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Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

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Vol. XIX, No. 6 APRIL, 1960

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COVER: A brief display of northern lights on the evening of February 27, 1960, photographed by Dale P. Cruikshank at Des Moines, Iowa. This picture was taken at 10:07 p.m. Central standard time, the exposure being seven seconds on Tri-X roll film, at f/3.5 with a Yashica 635 camera. Many of the fainter vertical rays were invisible to the eye. The light between the houses comes from a shopping center about a mile east of Mr. Cruikshank's home, and accounts for much of the sky illumination. By the time he moved to a darker location, however, the aurora had ended, as noted in his letter in the adjoining column.

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LETTERS

Sir:

Enclosed is an enlarged print [front cover] of an unusual aurora I observed about 10 p.m. February 27th, with the sky rather hazy. The very bright, narrow ray extended 40 to 45 degrees up the eastern sky, at an azimuth of about 75 degrees. There was no visible auroral activity in the north, but a shorter and fainter spike was seen in the south. From the western horizon a broad, faint band extended to near the magnetic zenith.

The picture shows more rays than were visible with the unaided eye. But when I drove to a darker part of the city, about 10:15 p.m., the aurora had vanished.

DALE P. CRUIKSHANK
3655 67th St.
Des Moines 22, Iowa

Sir:

Many years ago, I had the opportunity of working with G. W. Ritchey on the 40-inch Naval Observatory reflector which is now in Flagstaff, Arizona. I have retired from ordnance engineering at the Naval Gun Factory, and wish to dispose of a 24½-inch disk of Corning pyrex glass. Perhaps some reader would be interested in acquiring it.

One side of the disk has been figured to a paraboloid of 12 feet focal length, and is uncoated. The other side is ground to a sphere of 60-inch radius and is already aluminized. The edge thickness of the glass is four inches, but the center is only 2½ inches, the paraboloid being ¼ inch deep and the sphere 1¼ inches.

An elliptical secondary, aluminized, is available for Newtonian mounting of the paraboloid. But if the mirror were used to make a fast Schmidt system, supporting devices could be placed against the paraboloidal side.

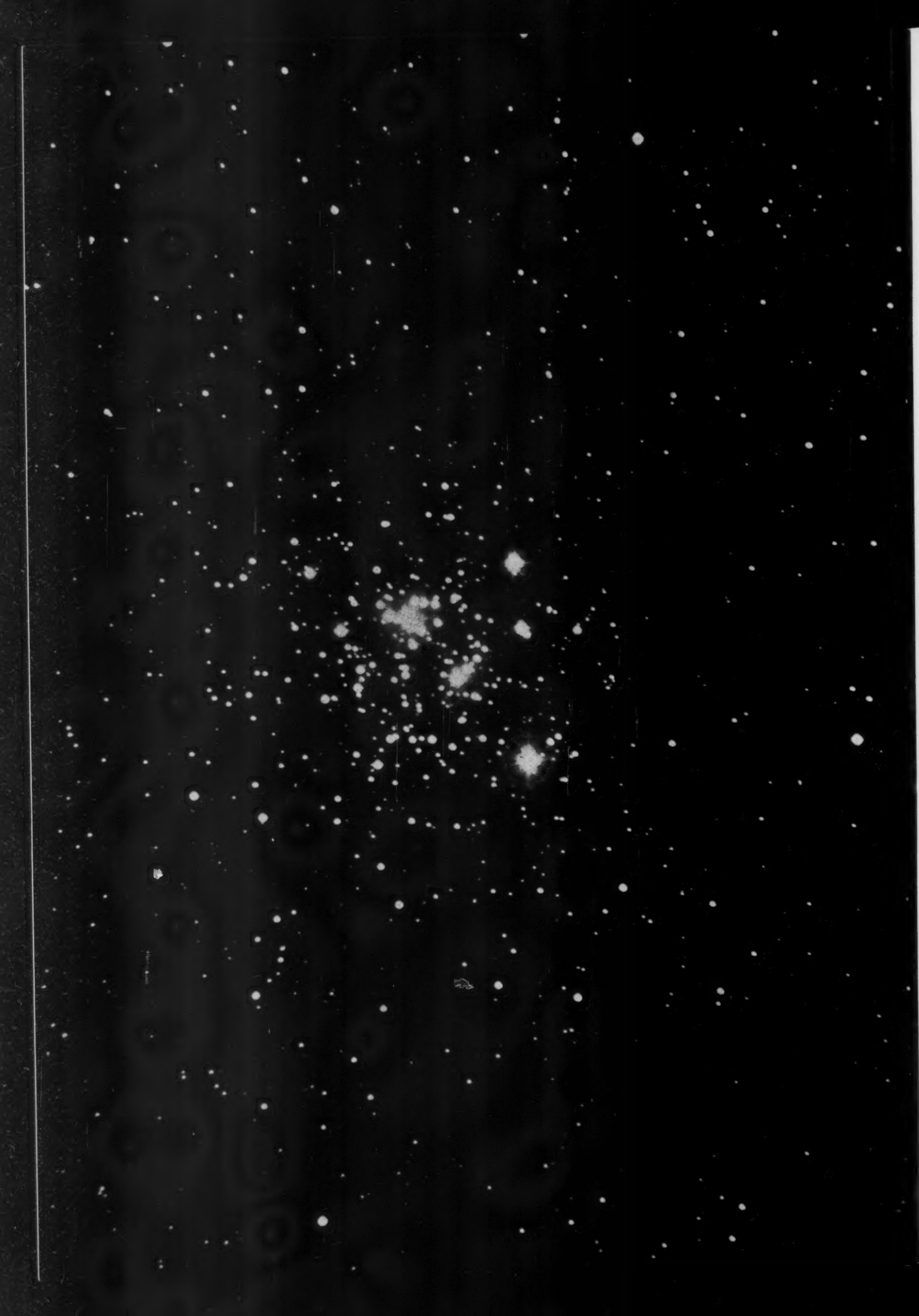
WILLIAM H. EVANS
503 Foxen Dr.
Santa Barbara, Calif.

Sir:

I am writing a book, whose present title is *Some Modern Amateurs' Telescopes,* which will describe about 50 selected telescopes in different parts of the world. Preference is given to instruments with which published observations have been made, or having special features.

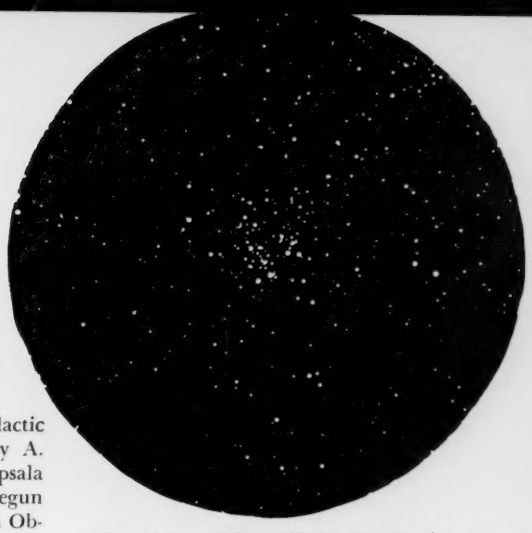
Any amateur who wishes his telescope to be considered for inclusion is invited to send me a very brief description of the instrument and its work, with a photograph or two. Everything received will be acknowledged, but it may take a little time to provide full replies.

S. H. DENNINGTON
30a Hill Crescent
Bexley, Kent, England



The Structure of Galactic Clusters

OTTO STRUVE, *National Radio Astronomy Observatory**



The cluster NGC 663 in Cassiopeia is highly concentrated toward its center, and has a diameter of 22 minutes of arc. A. Wallenquist finds for it a high c value, 9.49 (see text). From Markaryan's atlas of clusters.

IN RECENT YEARS, many astronomers have devoted much time and effort to the study of the galactic (or open) star clusters, for these systems "form the backbone of the Milky Way," as Helen Sawyer Hogg has phrased it, and because they serve to indicate reliably the ages of different groups of stars.

Approximately 500 galactic clusters have been catalogued, but many more can be recognized on photographs taken with the 48-inch Schmidt telescope of Palomar Observatory. As a rule, a galactic cluster contains dozens or hundreds of stars, but the richest examples, among them the Double Cluster in Perseus, may have as many as 1,000. With very few exceptions, the galactic clusters are located close to the central plane of the Milky Way.

Even a superficial examination of photographs shows that clusters differ significantly in number of stars, in central condensation, and in angular diameter (though this last characteristic depends on distance as well as on the clusters themselves). More detailed studies, of the spectral types and absolute magnitudes of the member stars, indicate that the open clusters also differ greatly in their Hertzsprung-Russell or spectrum-luminosity diagrams. (For practical reasons, usually the colors of the stars are measured instead of their spectra, so the comparison is actually between color-luminosity diagrams.)

Therefore we can distinguish in a rough way between *young* clusters, which contain very blue stars of spectral classes *O* to *B2*; clusters of *intermediate age*, with spectral classes of *B3* to *B8*, but without any very blue stars; and relatively *old* clusters, with no stars bluer than *B8*. Thus NGC 2362 and the Double Cluster would be young, the Pleiades of intermediate age, while NGC 752 and Messier 67 would be classed as old.

A particularly interesting memoir on the structural properties of 67 galactic clusters has just been published by A. Wallenquist, in the *Annals* of Uppsala Observatory in Sweden. He had begun this study 27 years ago at the Bosscha Observatory in Java, and continued it in later years at Uppsala. In 1947 he observed southern clusters at the Cordoba Observatory in Argentina. He also drew upon the results of many other astronomers, notably R. J. Trumpler and James Cuffey in the United States. The investigation was completed early in 1959.

In Wallenquist's procedure, the average magnitude of the five brightest stars in each cluster was determined and a value four magnitudes fainter was then adopted as the limiting brightness for his star counts. Next, he drew concentric rings of regularly increasing radii around the center of the cluster, and counted the number of stars within each ring. To estimate the number of foreground and background stars in each cluster's area, he extended the counts far beyond the obvious limits of the cluster.

Thus he was able to compute the mean areal density of each ring and correct it for the effect of stars in the field that were not members of the cluster, then plotting the areal densities as a function of distance from the cluster's center. The last step was to convert these densities per unit area to densities per unit volume, that is, to change from areas on the sky to volumes of successive shells around the cluster's center.

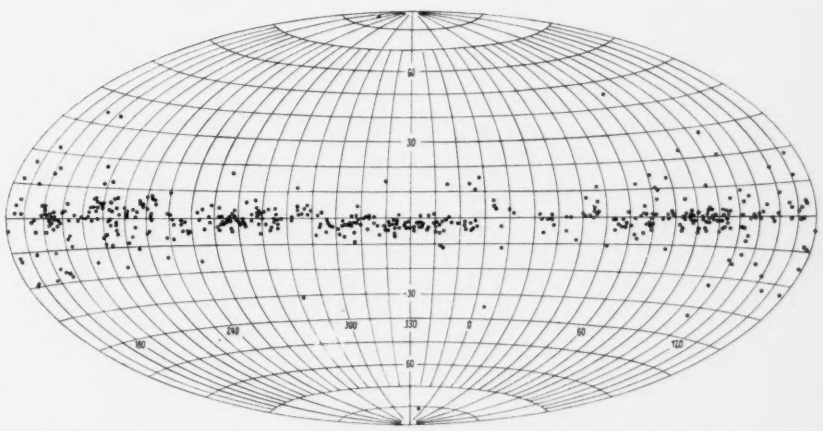
As an example of this procedure, let us trace what Wallenquist has done for M67, a striking stellar group in Cancer that is well known to amateurs who observe the springtime sky. It is also known as NGC 2682, and is located 33 degrees north of the central plane of the Milky Way.

In M67, the average apparent photographic magnitude for the five brightest stars is 11.6. The star counts were made down to a limit four magnitudes fainter than this, or 15.6. The radius of the cluster, defined as the distance from the center at which the number of stars per unit area has diminished to that of the background field, comes out as 9.0 minutes of arc, and the number of stellar members brighter than 15.6 is about 157.

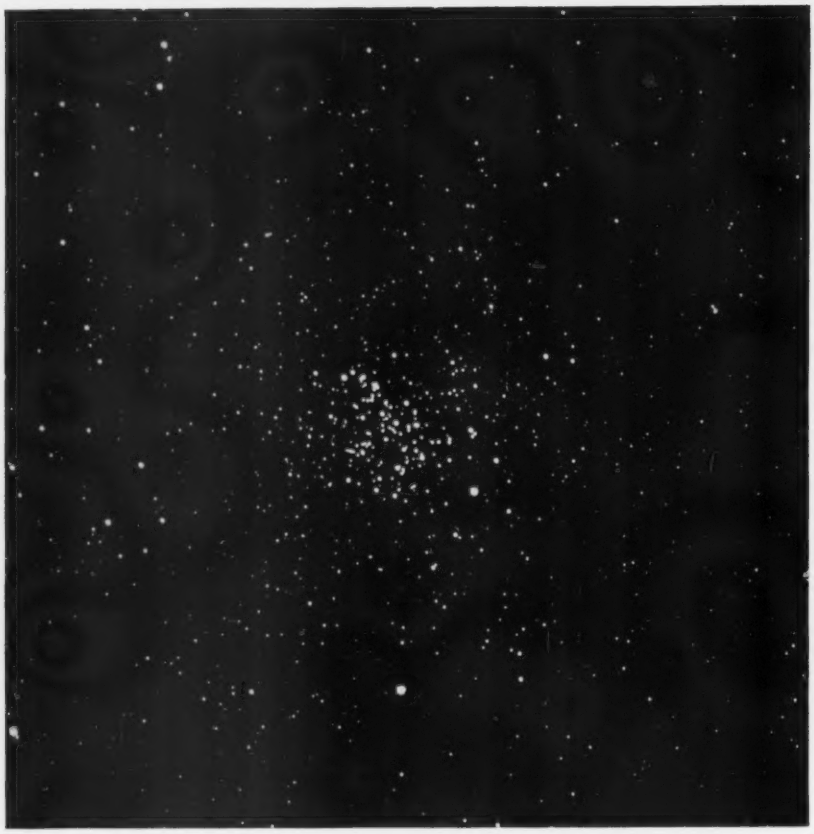
For the first 10 concentric rings, covering the cluster, Wallenquist then determined the number of stars within each,

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.

FACING PICTURE: Among the finest open clusters in southern skies is NGC 4755, near the Southern Cross. This is Kappa Crucis, distinctly visible to the unaided eye. According to Wallenquist, it has 44 member stars brighter than magnitude 10.9, and a diameter of 13 minutes of arc. He finds its distance to be 4,700 light-years. Harvard Observatory photo.



The galactic clusters are concentrated along the central line of the Milky Way (the horizontal diameter of this diagram). Adapted from Helen Sawyer Hogg's monograph on star clusters in "Handbuch der Physik," Vol. 53.



Messier 67 in Cancer. This area of one square degree is enlarged from a 90-minute exposure by Bart J. Bok with the Jewett Schmidt telescope on December 10-11, 1948. Harvard Observatory photograph.

in terms of the central area as a unit. These areal densities were then converted to space densities of concentric shells, given in the accompanying table, in which the mean radius of each ring is expressed as a fraction of the radius of the cluster itself, taken as nine minutes of arc.

MESSIER 67

Ring (Shell)	*Mean Radius*	*Areal Density*	*Shell Density*
1	0.07	1.000	1.000
2	0.16	0.915	0.751
3	0.25	0.823	0.697
4	0.35	0.688	0.659
5	0.45	0.481	0.574
6	0.55	0.242	0.230
7	0.65	0.146	0.127
8	0.75	0.088	0.090
9	0.85	0.038	0.042
10	0.95	0.011	0.016

In order to represent the tabulated densities and similar numbers for each cluster, Wallenquist chose the following formula for the star density d at a distance w from the center (expressed in fractions of the cluster's radius):

$$d = d_0 (1 - w)^c,$$

where d_0 is the central space density and c is a constant to characterize the degree of concentration of the stars toward the center of the cluster.

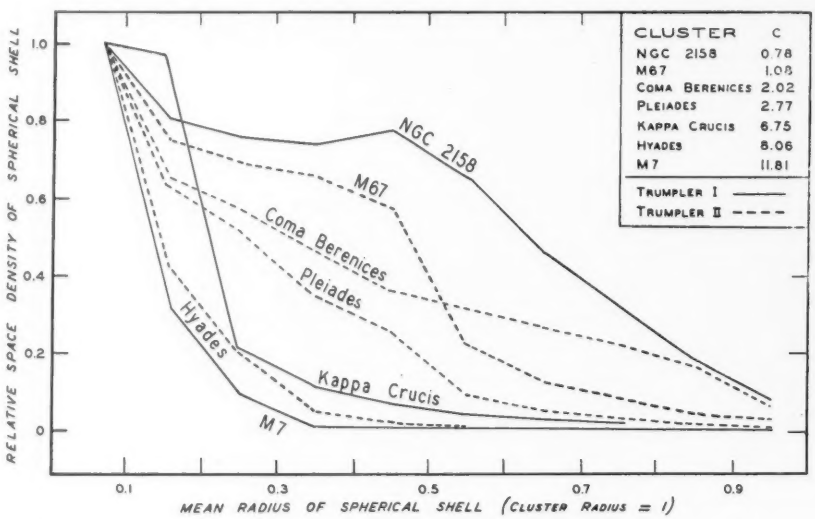
As long as we are interested only in relative concentration, we can assume $d_0 = 1$, for simplicity. Then at the center of each cluster $w = 0$ and $d = 1$, while at the extreme edge $w = 1$ and $d = 0$. The nature of curves represented by Wallenquist's formula for various values of c is easily seen. If c is quite large, the curve of d plotted against w drops very rapidly, and the cluster is highly condensed. If $c = 1$, the curve is an oblique straight line, while for $c = 0$ it would be horizontal, corresponding to a cluster of uniform space density throughout.

In the case of M67, Wallenquist found that the constant c was 1.08. Among the 67 clusters he investigated, the largest c value was 11.81, for M7, and the smallest was 0.78, for NGC 2158. In all cases, the space density decreases outward from the center, but the rate of this decrease varies greatly from cluster to cluster. There is thus a wide range in the degree of central concentration, just as direct inspection of cluster photographs suggests.

Many years earlier, Trumpler had made such a study. From his inspection of the appearances of clusters on photographs, he arranged them into four groups. Group I included those with the strongest apparent central condensation; at the other extreme, group IV represented loose arrays, without appreciable concentration toward the center, that merge into the background of the Milky Way.

Wallenquist's results are based on actual star counts, and therefore should give a more precise description of the structures of the clusters. Yet it is strange, at first sight, that he finds no correlation of his c numbers with Trumpler's classes I, II, III, and IV. He remarks, "It does not seem possible in most cases to draw any definite conclusions as to the real concentration of the stars towards the centre of the clusters merely on the basis of superficial inspections of the clusters." This statement appears to me to be an exaggeration; perhaps there are other reasons for the lack of correlation.

In the first place, Wallenquist and Trumpler do not use the same definition for central condensation. A cluster where c is near zero has a very abrupt edge, yet



For each of seven Wallenquist clusters, the curve shows how the space density (number of stars per unit volume) falls off as the edge of the cluster is approached. Listed in the upper right are the c numbers computed by Wallenquist to describe the degree of concentration of individual clusters.

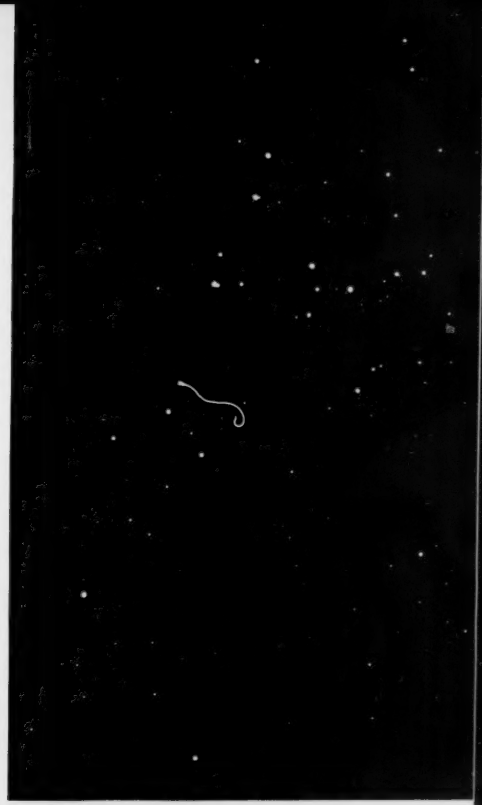
Trumpler would regard such an edge as indicating strong concentration. As a matter of fact, two of the smallest c values determined by Wallenquist (0.78 for NGC 2158 and 1.58 for M50) belong to clusters typed as I by Trumpler. At the same time, a cluster with a large c number would also be regarded by Trumpler as belonging to his most concentrated type, I. Mostly among clusters with intermediate c's should we expect Trumpler's classes III and IV. Although the material is not sufficient to prove these relations, there is reason to believe that the two systems of classification are not incompatible.

The best direct photograph of NGC 2158 known to me is a Palomar Observatory one with the 48-inch Schmidt camera (reproduced on page 297 of last month's issue). This cluster, according to Wallenquist, has a diameter of only six minutes of arc, and contains about 250 stars brighter than photographic magnitude 18.6. He had to extrapolate Cuffey's original data by about $1\frac{1}{2}$ magnitudes, and similar extrapolations were made for a few other clusters.

For clusters this faint and distant, the question arises whether the c values are as reliable as for larger, nearby systems. This table is compiled from Wallenquist's data:

Angular Radius	*Mean c*	*Clusters*
2′ to 5′	3.2	8
5′ to 8′	3.7	13
8′ to 12′	5.3	12
12′ to 17′	5.5	11
17′ to 25′	6.2	12
Over 25′	5.9	11

It would appear from this listing that clusters with small angular radii have smaller values of c, which might at first be interpreted as a systematic effect of observational difficulties. But the clusters themselves differ in linear size as well as in distance, and it may be that the intrinsically large ones tend to be more concentrated. This is, in fact, just what Wallenquist proceeded to find after determining the actual linear dimensions of his clusters.



The Coma Berenices cluster, a favorite object in the spring sky for amateurs. Though this grouping of naked-eye stars was famed even in antiquity, not until 1915 was it recognized as actually a sparse star cluster, of huge apparent size because of its small distance, 250 light-years. This photograph with a wide-field 8-inch refractor shows Gamma Comae $\frac{1}{2}$ inch below top center; 23 Comae is near the lower left edge. Harvard Observatory photo.

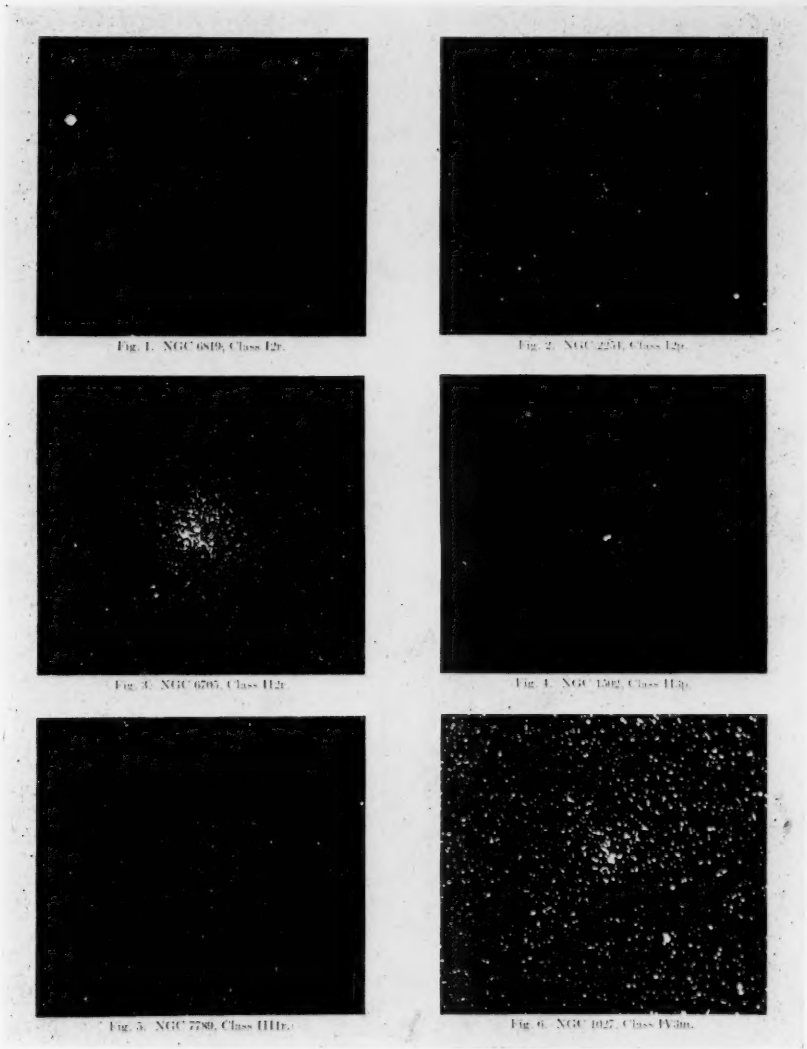


Fig. 1. NGC 6819, Class I2r.

Fig. 2. NGC 2251, Class I2r.

Fig. 3. NGC 6705, Class II2r.

Fig. 4. NGC 1502, Class II3p.

Fig. 5. NGC 7789, Class IIIr.

Fig. 6. NGC 1027, Class IV3m.

R. J. Trumpler chose these six clusters to illustrate his classification into four types, ranging from I, most condensed, to IV, very scattered. His method employed direct inspection of photographs, rather than star counts. From Lick Observatory "Bulletin," 1930.

Previous studies by several astronomers have given reliable distances of 16 "standard" clusters on Wallenquist's list, on the basis of their H-R diagrams. To derive distances for the other 51 objects, Wallenquist assumed that all clusters having similar distributions of space density resemble each other in other properties.

Thus he could compare the angular radius of a cluster with that of a standard cluster having the same value of c. The ratio of the two angular radii then expressed the inverse ratio of their distances. Having found the distances of all his clusters, the Swedish astronomer could compare their linear diameters in parsecs. His table (see page 332) indicates that there is, in fact, a strong tendency for intrinsically large clusters to show greater central concentration (higher c values).

As a further test on the reliability of his results, I have tabulated the average

The Double Cluster in Perseus, photographed by S. R. B. Cooke with a 6-inch Schmidt camera he built himself. Both clusters are easy naked-eye objects, each appearing full-moon size. At the left is h Persei, for which Wallenquist's c value is very high, 11.49; at the right, Chi Persei has a c value of 9.95. Both objects are Trumpler class IV, and their average distance is about 7,400 light-years according to H. L. Johnson. South is upward.

Values of c	*Diameter in parsecs*						
	3-5	5-7	7-9	9-11	11-13	13-15	16-18
0.0-1.9	3	2	0	0	0	0	0
2.0-3.9	4	12	5	3	0	0	0
4.0-5.9	5	8	2	0	1	0	0
6.0-7.9	1	8	1	0	0	0	0
8.0-9.9	0	2	2	2	1	2	1
10.0-11.9	0	1	0	0	0	0	1

values of *c* for seven different distance groups, ranging from clusters nearer than 300 parsecs to those farther than 2,000. The result is clear-cut: no dependence of degree of concentration upon the distance.

Distance of Cluster (parsecs)	*Mean c*	*Clusters*
Under 250	4.1	4
250-500	6.1	9
500-750	5.5	13
750-1,000	5.4	12
1,000-1,500	4.6	10
1,500-2,000	5.2	11
Over 2,000	3.3	8

These tests justify belief in the reliability of Wallenquist's *c* values, except perhaps for the most distant objects. This is natural, for very remote clusters are small in angular size and contain only apparently faint stars; hence, large corrections must be applied to the star counts in subtracting out the field stars. Undoubtedly, the Swedish astronomer has uncovered a cosmogonically important relation between central condensation and linear diameter.

From his data, the following picture can be drawn of an average galactic cluster. If we include only the members down to four magnitudes fainter than the average of the five brightest stars, there are about 12 stars per cubic parsec in the central region, and about 0.7 star per cubic parsec for the cluster as a whole. The magnitude limit corresponds, for the average of the 30 clusters with the best known distances, to an absolute magnitude of about +3.8. In the vicinity of the sun each cubic parsec contains only about 0.0023 star that luminous or up to four magnitudes brighter. Therefore, the space density of stars in the central part of a typical galactic cluster is about 5,000 times greater than that in the solar neighborhood. In exceptionally dense clusters, this factor may exceed 40,000.

The cluster NGC 2324, in Monoceros, is among those with little central condensation, according to Wallenquist, whose c value is 2.76. This is a 15-minute exposure in blue light with the 36-inch reflector of Goethe Link Observatory, by James Cuffey. The 1950 position of this cluster is $7^h\ 00^m.4$, +1° 08′, and its diameter is about 10 minutes of arc. Indiana University photograph.

When the clusters are sorted into the three age groups, young, intermediate, and old, it is found that the degree of concentration, *c*, decreases from 6.7 for the young ones, through 5.3 for those of intermediate age, to 4.6 for the older ones. The central and the average space densities tend to increase with age. Furthermore, the oldest clusters lie, on the average, at greater distances above and below the central plane of the Milky Way than do the youngest ones.

All these correlations suggest, according to Wallenquist, that "the younger clusters are, like associations, loose aggregations with low densities and, from [the] dynamical point of view, fairly unstable systems with short lifetimes. The clusters with large densities are on the other hand more stable systems and may therefore have long lifetimes and high average age."

SOVIET JOURNAL

One of the world's leading astronomical periodicals is the Russian-language *Astronomical Journal*, issued by the U. S. S. R. Academy of Sciences. It is now available in a cover-to-cover English translation, *Soviet Astronomy-AJ*, published by the American Institute of Physics with the co-operation of the American Astronomical Society.

The cost for six issues, beginning with those of 1957, is $25.00, but only $10.00 for libraries of nonprofit academic institutions; add $2.00 in either case for countries other than the United States. Subscriptions should be sent to Circulation Manager, American Institute of Physics, 335 E. 45th St., New York 17, N. Y.

AAS TO MEET IN PITTSBURGH

The American Astronomical Society's 105th meeting will be held at the University of Pittsburgh on April 18-21. Features of the Pennsylvania program are a symposium on subdwarf stars and an address at the Buhl Planetarium by Otto Struve, on the National Radio Astronomy Observatory.

ASP MEETING IN OREGON

The Astronomical Society of the Pacific will hold a meeting at the University of Oregon in Eugene, on June 13-15, jointly with the Pacific division of the American Association for the Advancement of Science. The program committee of the society may be contacted through George O. Abell, Department of Astronomy, University of California, Los Angeles, Calif.

NEWS NOTES

REPORT OF NEW PRINCIPAL PLANET UNFOUNDED

Many newspapers in February carried a story that a new planet beyond Pluto had been discovered at an observatory in Soviet Central Asia. The source was an article in the newspaper *Kazakhstanskaya Pravda* for February 6, 1960, whose original text has now become available. It appears that the new object was not a trans-Plutonian planet but a faint unlisted asteroid, photographed in Capricornus in August, 1957, by Edward Denisiuk at the Mountain Observatory of the Kazakh Academy of Sciences, near Alma-Ata.

At that time, he could not recognize images of the faint object on a sufficient number of photographs to allow an orbit calculation. Recently, however, the asteroid was detected on additional plates of 1957, with the aid of a new blink comparator, in which images that have moved or otherwise changed appear red or blue, while all other images appear black. This device was designed by D. Rozhkovsky, director of the Kazakh Astrophysics Institute.

EJECTION OF MATTER FROM RED GIANT STARS

Many giant and supergiant stars of spectral class *M*, as well as some *K* stars, appear to be surrounded by large expanding envelopes of gas. Their presence is indicated by violet-displaced sharp absorption components of the H and K lines of ionized calcium in their spectra. The most completely studied case is the *M*-type component of the visual binary Alpha Herculis (SKY AND TELESCOPE, April, 1956, page 252).

This star has a gaseous shell about 1,000 astronomical units deep, which A. J. Deutsch has shown to be expanding at a constant rate of 10 kilometers per second. In other similar stars, all species of atoms move together, at velocities much less than the stars' escape velocities at their surfaces. And there is comparatively little range in the measured ejection velocity from star to star, all being between six and about 23 kilometers per second.

Astronomers have been puzzled by the velocity being the same at different distances from the star. The explanation may lie in a suggestion made by O. C. Wilson, Mount Wilson and Palomar Observatories, in the *Astrophysical Journal* for January, 1960.

In the ultraviolet spectrum of a red supergiant star, the Lyman-alpha line of hydrogen at 1216 angstroms can be expected to appear as an intense emission feature. Hence, by absorbing this radiation a hydrogen atom in the immediate vicinity of the star can gain momentum and be accelerated outward against the star's gravitational field. But as the atom's velocity increases, the Doppler displacement will soon reduce the amount of Lyman-alpha radiation it can absorb, and it will no longer be accelerated. Dr. Wilson writes:

"As the velocity increases, the Ly-α line will apparently shift redward, as seen from the atom, until, after a time, the atom 'slides down' the violet edge of the line. At this point the atom begins to lose its radiative support, which decreases with respect to the gravitational attraction of the star. At some point near the line edge, the atom will be in equilibrium under zero average net force and will continue to move outward at the corresponding velocity. Any slight velocity change in either sense will tend to be corrected automatically."

The shell of the star, therefore, apart from its innermost portions, would be expanding at a uniform rate, as observed for Alpha Herculis. While this radiation-pressure effect can act only on hydrogen, the most abundant element, other constituents of the stellar atmosphere will be dragged along.

Dr. Wilson points out that his mechanism would be ineffective in ejecting hydrogen from stars as small and hot as the sun, since the radiation pressure of solar Lyman-alpha would not predominate sufficiently over gravitational forces. It would work for late-type supergiant stars because of their lower surface gravities, provided their chromospheric temperatures were high enough.

S. A. MITCHELL PASSES AWAY

Few if any other astronomers have seen as many total eclipses of the sun as Samuel Alfred Mitchell, who died on February 22nd at the age of 85. The Canadian-born scientist, who was director from 1913 to 1945 of the University of Virginia's Leander McCormick Observatory, took part in 10 eclipse expeditions between 1900 and 1937.

S. A. Mitchell, director of McCormick Observatory from 1913 to 1945.

His rare good luck with weather allowed him to see the corona on all but two of these occasions, and none had rain or complete overcast. Dr. Mitchell's book *Eclipses of the Sun*, giving a popular account of his expeditions, first appeared in 1923.

The primary purpose of all these eclipse travels (covering 90,000 miles) was to observe the flash spectrum — the bright-line spectrum of the solar chromosphere, which is briefly visible immediately before and after totality.

At McCormick Observatory, Dr. Mitchell and his collaborators used the 26-inch refractor for the photographic measurement of star distances. On his retirement in September, 1945, about 1,700 trigonometric parallaxes had been completed. With the same instrument, he determined visual magnitudes of comparison stars for many long-period variables, to serve the needs of the American Association of Variable Star Observers.

BIG REFLECTOR PLANNED FOR ARGENTINA

La Plata Observatory in Argentina is planning to erect a reflecting telescope of at least 80 inches aperture. The University of La Plata has authorized the observatory to call for construction bids and has allocated funds. A site survey is to be undertaken in western Argentina, between latitudes 26° and 35° south, a region that meteorological data indicate as the most promising.

IN THE CURRENT JOURNALS

DUST AND GAS BETWEEN THE EARTH AND THE SUN, by R. O. Redman, *Observatory*, October, 1959. "Astronomers want to know where interplanetary matter arose, whether it comes mainly from interstellar space, whether most of it has always been scattered about the solar system ever since its formation, or whether it arises by ejection of matter from the Sun."

COSMOGENIC RARE GAS CONTENTS OF IRON METEORITES, by Oliver A. Schaeffer, *Physics Today*, February, 1960. "One can see the possibility of obtaining good estimates of the original age of meteorites before entering the earth's atmosphere, as well as the times the meteorites have been in space and on the earth."

THE SPACE ENVIRONMENT, by Homer E. Newell, Jr., *Science*, February 12, 1960. "Of great interest in all considerations of manned flight into space is the new environment that man will encounter. During such flights we may expect to learn more about the environment itself. But we may also expect to learn more about man, as he faces and copes with that environment."

A Theory of the Origin of Lunar Rills

GILBERT FIELDER

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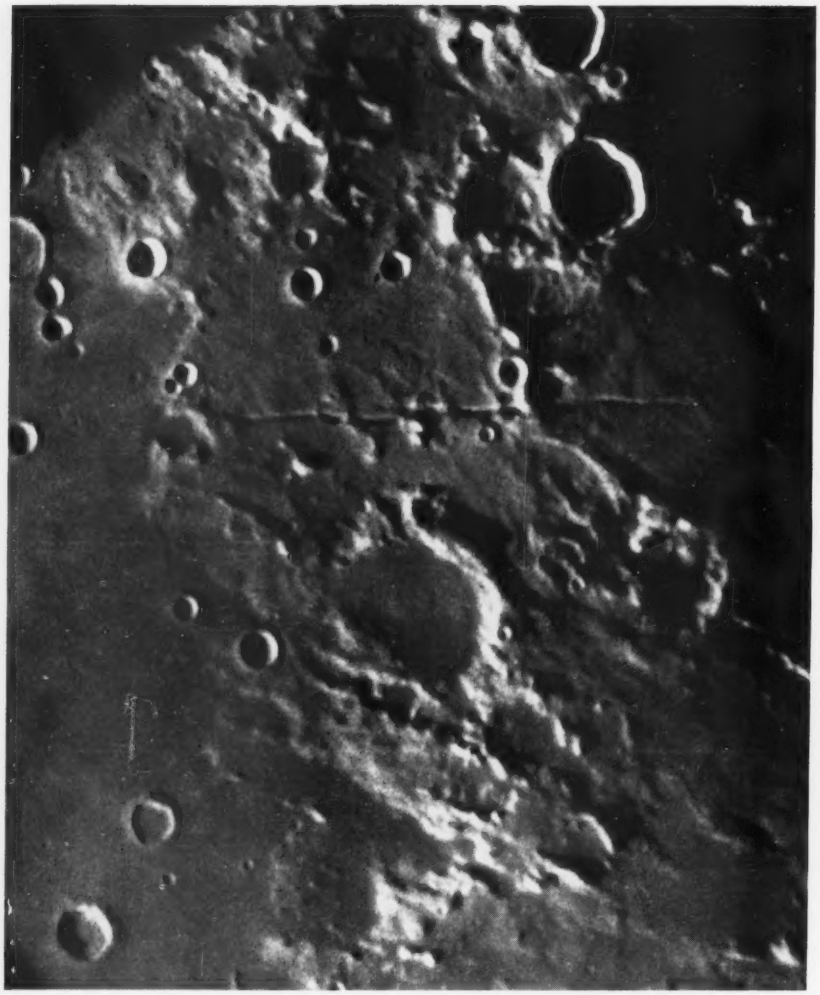


A long trench stretching across the central part of the moon's surface is the Ariadaeus rill, named after the larger of the twin craters at its left (western) end. This photograph was taken with the 24-inch refractor of Pic du Midi Observatory on June 16, 1956, soon after sunrise on this part of the moon. Compare this and the overlapping photograph on the facing page with the author's key chart, whose three sets of parallel lines show directions of lunar ridges and furrows. Pic du Midi Observatory photograph.

DISTRIBUTED over the visible face of the moon are many hundreds of major rills. Two of the most prominent and best known are the Hyginus and Ariadaeus rills, pictured here and in the lunar photograph on page 150 of SKY AND TELESCOPE for January. These two are readily observed even in small telescopes.

In general, rills are like trenches, sometimes 200 to 300 kilometers long, a few kilometers wide, and in depth frequently about a third of their widths. In many cases, ridges run along their bottoms. As observations of the Ariadaeus rill demonstrate, they are not simply cracks in the lunar surface.

When the directions of lunar rills, faults, and ridges are charted, they tend to form a pattern of overlapping parallel arrays, known as the lunar grid system. Although R. Baldwin has criticized grouping these three classes of objects in the same analysis, I believe there is a fundamental connection between the directions of rills, faults, and mountain striae.*

A fault in the moon's surface may be classed as a *thrust, wrench,* or *normal fracture*. The stress at any point in the lunar crust may be resolved into three components, two horizontal and at right angles to each other, the other vertical. If the greatest component is horizontal, it may cause one portion of the surface to ride up over another, producing a thrust fault. Or it may cause one portion to slide past an adjacent area, this shearing action forming a wrench fault. Finally, where the strongest component is vertical, the raising or lowering of one part of the surface will produce a normal fault between it and adjoining regions. When the weakest stress component is vertical, thrust faulting may occur at small depths.

When thrust faults occur, the plane of throw or fracture is always inclined at angles considerably less than 45 degrees to the direction of the strongest stress component. (This angle is about 23 degrees for granites and basalts.) For normal faulting, the plane of throw is between 45 and 90 degrees to the horizontal, in a direction perpendicular to the least principal stress.

These phenomena are familiar to geologists in terrestrial applications, and it is my belief that they may be used to explain the principal features of the Ariadaeus and Hyginus rills. Neither object is associated with high mountains, such as may be expected to lead to normal faulting, and I therefore have looked for indications that thrust and wrench faults are involved, as a result of horizontal forces.

Look first at the sketch of the region, noting how Ariadaeus and Hyginus are linked by another rill, which is a key feature in the interpretation I propose. Then observe how the rills have directions related to those of nearby ridges, which seem to form three families. The members of each family run roughly parallel, though the families themselves have three different directions.

Often, the ridges form parts of the walls of craters, many of which have been deformed almost beyond recognition. The broken curves in the sketch map indicate their probable original outlines. These ruined craters clearly antedate the distortions and must therefore be very ancient.

It seems plausible that these ridges or striae represent overthrusts or folds caused by unequal horizontal pressures. Heretofore several writers, including myself, have suggested that the prominent striae of the

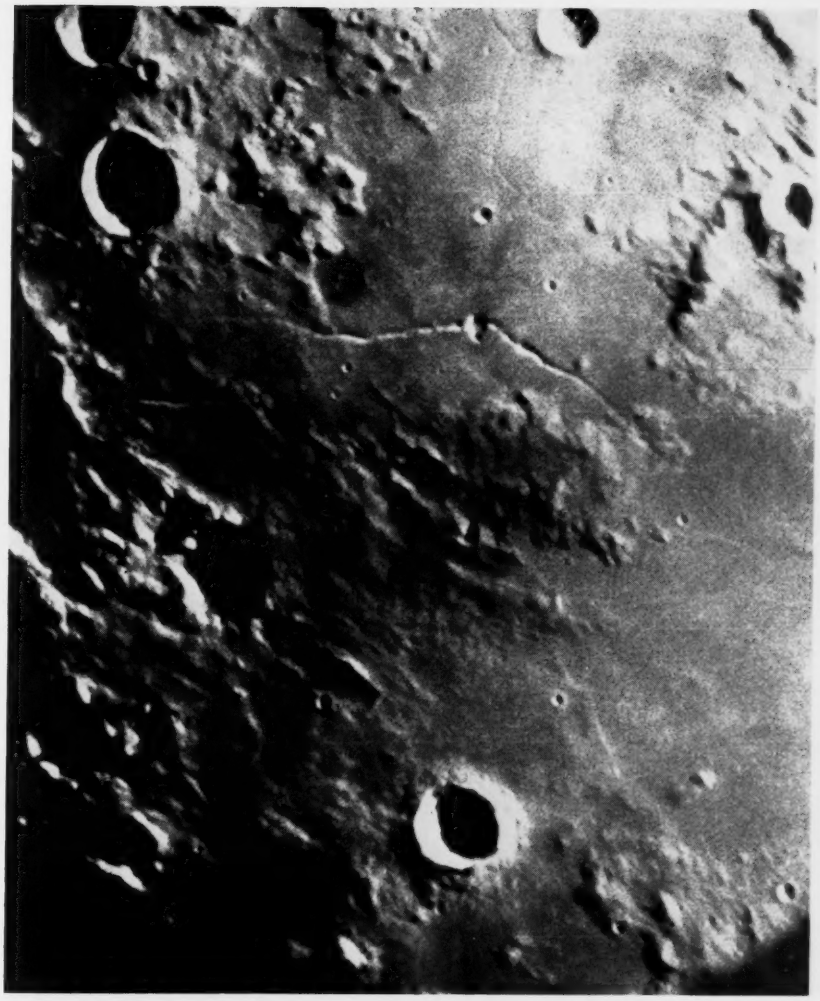
*These matters were discussed by the author in the *Journal* of the British Astronomical Association, *67*, 60, 314, 1957; by V. A. Firsoff on page 309 of the same volume; and by the author in *Publications* of the Astronomical Society of the Pacific, *70*, 308, 1958. The discovery of the convex bottom of the Ariadaeus rill was reported in *L'Astronomie*, *70*, 383, 1956.

best-developed family (running roughly northeast to southwest) originated as part of a collisional explosion centered in Mare Imbrium. That hypothesis cannot account for all the parallel linear formations simply by the grooving action of projectiles and by the splashing silicates, since it is evident that many of the ridges have a less superficial origin.

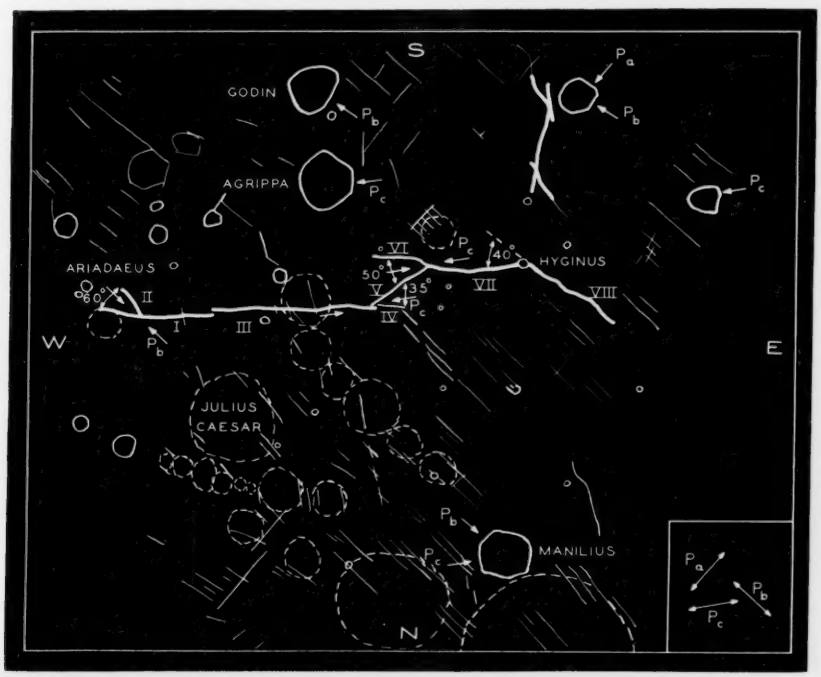
A second, less well-developed family runs perpendicular to the first, while the third and possibly weakest set goes from north-northeast to south-southwest. We shall assume that these three families originated from transverse horizontal pressures, $\mathbf{P}_a$, $\mathbf{P}_b$, and $\mathbf{P}_c$, respectively, each acting independently of the other and at different periods of lunar history. Their directions, indicated on the sketch, have been determined from the trends observed for the ridges and striae in the Ariadaeus-Hyginus region, but independently of the directions of the rills.

In the sketch, parts of the two main rills have been labeled with Roman numerals, starting at the western end of Ariadaeus, where **I** and **II** join at an angle of about 60 degrees. Farther east **IV** and **V** meet at about 35 degrees, while **V** and **VI** (Hyginus rill) make an angle of about 50 degrees. The direction of the transverse pressure $\mathbf{P}_b$ approximately bisects the first angle **(I-II)**, and $\mathbf{P}_c$ bisects each of the other two. If we consider a shifting of the lunar surface within these angles with respect to the surface outside of them, it is evident that the associated rills could follow wrench faults.

Such fractures are usually more nearly perpendicular to the surface than normal faults; thus, they may tap a deeper layer of the moon than other faults do. Presumably the moon contains, or used to contain, at least isolated chambers of magma. Can we consider rills to be dikes, where molten material has risen along these already existing fractures?

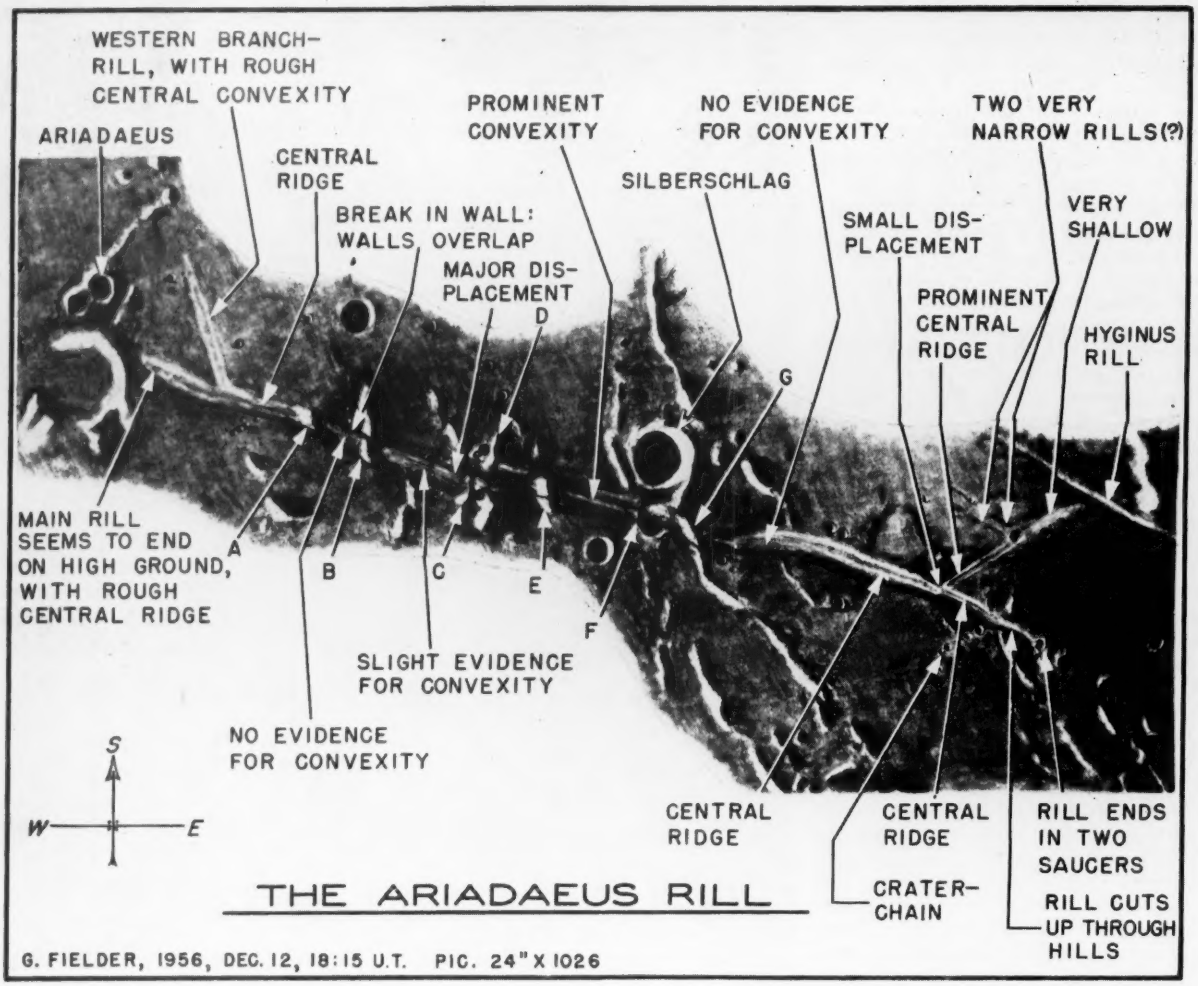


Another Pic du Midi photograph, of November 24, 1956, shows the Hyginus rill and, to its left, the eastern extremity of the Ariadaeus rill, pictured opposite.



If so, the rills would appear to be of two kinds: those associated with normal fractures and the mountain masses, and the wide, prominent rills of the Ariadaeus-Hyginus system that originated deeper in the moon. In the two cases, the intruding magmas may have differed in chemical composition and physical conditions, yielding rills of different dimensions. On Earth, dikes are rarely intruded along wrench fractures, because the latter are held closed by compression, but such a fracture could be opened by subsequent tension of the surface layers.

After the fractures formed, relief of pressure would lower the melting point of any trapped magma. If its specific gravity was greater than that of the surrounding rocks, the melt would not, subject to equal horizontal pressures, reach the surface of the moon. The sides of the fractures would be displaced outward, yet no such movement of the *surface* has been detected. Whatever movement of this kind

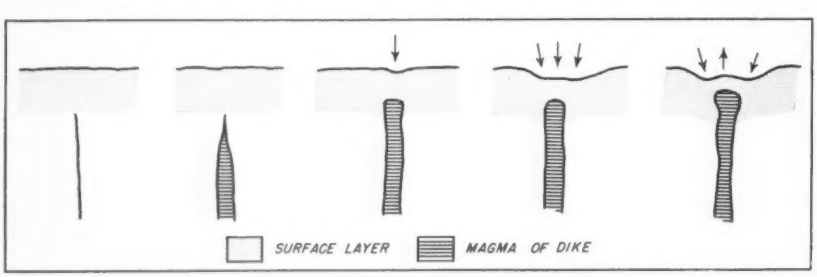


The author used a magnification of 1,026 with the Pic du Midi 24-inch refractor in making this drawing of details in the Ariadaeus rill. Compare it with his photograph with the same telescope on page 334.

that may have occurred is probably not more than one-tenth of the widest rill's width.

Rock debris may be seen on the slopes and bottoms of the broader rills, and the longitudinal ridges within the rills often appear to be blocky and of irregular contour. It would seem that the rising magma had undermined the essentially fragmentary surface layer of the moon, and then subsided. Rocks were engulfed and detached, and there was further subsidence, so the rill became considerably wider than the original dike.

The ridges across the Ariadaeus rill slumped into it as a result of this subsidence. Meanwhile, the magma tended to a level consistent with hydrostatic equilibrium, thereby forcing up the central longitudinal ridges. The same mechanism probably arched the cross ridges to some extent. The diagram shows the proposed sequence of events.



Five stages in the formation of a lunar rill, according to the explanation proposed by Dr. Fielder. Molten magma rises in a pre-existing fracture, weakening the overlying layers and causing them to subside. This can be followed by the appearance of a central ridge, extending along the floor of the rill.

Inspection of the photographs indicates that the walls of the well-formed craters Godin, Agrippa, and Manilius tend to be polygonal rather than circular. These three craters have been apparently modified by $\mathbf{P_b}$ and $\mathbf{P_c}$, but not by $\mathbf{P_a}$. On the other hand, the ancient craters (dashed outlines) have been affected more by $\mathbf{P_a}$ than the other two pressures, indicating that $\mathbf{P_a}$ acted before the others. Another piece of evidence agrees with this: Rills **I, III,** and **IV** are crossed by ridges older than themselves, those ridges being overthrusts evidently formed by $\mathbf{P_a}$ or $\mathbf{P_c}$.

Rill **VIII,** the eastern part of the Hyginus system, runs parallel to the best developed overthrusts. But it was not formed simultaneously with them unless it was associated with a thrust fracture, which seems unlikely. Since it is probably of about the same age as the other rills nearby, it would have been more recent than the overthrusts that made the ridges.

But this rill does not have quite the direction that would be expected if it lay along a wrench fault, unless it was deflected at shallow depths along previously existing folds of weakness.

Working on this problem, I made the detailed drawing of the Hyginus cleft reproduced here, using the 24-inch refractor of Pic du Midi Observatory. As was previously known, rill **VIII** contains a line of craterlets. These objects are not well formed. Their centers lie along the axis of the rill, and they must be associated in some way with the formation of this part of the rill itself.

By contrast, the western portion of the Hyginus rill, **VII,** contains a longitudinal ridge like that in Ariadaeus. There is no such convexity of the floor in **VIII.** Suppose in the latter case the magma was of low viscosity and actually became exposed to the surface. It would radiate heat rapidly into space, with the more volatile constituents concentrated in the top of the dike. The pressure of gases occluded in the magma might cause local explosions along the top of the seam, as soon as the gas pressure exceeded a critical value. It is suggested that the pseudo craters in rill **VIII** were formed in this way, which differs only in detail from the formation of the other parts of the Hyginus-Ariadaeus system.

In this article I have included some very useful suggestions by Prof. W. A. Deer, who read my original manuscript.

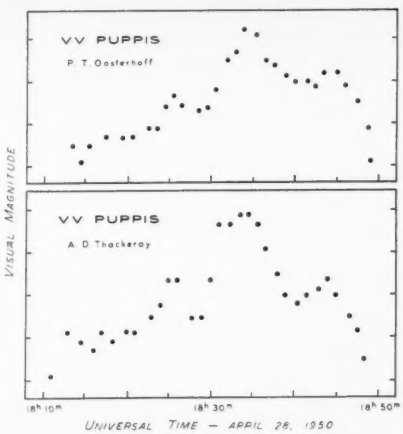
Dr. Fielder's drawing of the Hyginus rill was made on November 24, 1956, with the 24-inch refractor, 1,026x. Note the saucerlike depressions that make up much of the eastern (right-hand) branch. The large dark patch is the ruined crater Hyginus S. Compare this drawing with the direct photograph on page 335.

Some Observations of VV Puppis

IN 1931, a remarkable faint variable star in the constellation Puppis, having a period of only 100 minutes, was discovered by H. van Gent, of Leiden Observatory. For many years it was considered to be a pulsating variable of the RR Lyrae type, though with many peculiarities. In 1959, George H. Herbig, of Lick Observatory, announced the surprising finding that VV Puppis is actually an eclipsing binary, with a shorter period than any other known binary system (SKY AND TELESCOPE, July, 1959, page 493).

Dr. Herbig's spectrographic observations led him to propose that VV Puppis consists of a small darker star and a larger bright one, whose trailing edge contains a hot, very luminous patch. This model enabled him to account for the general character of the light curve, which has a minimum whose duration is more than half the light cycle.

Some hitherto unpublished visual observations by the authors, of a maximum on April 28, 1950, are of new interest in connection with Herbig's model. Our observations were made at the Newtonian focus of the 74-inch Radcliffe Observatory reflector at Pretoria, South Africa, using the same sequence of comparison stars as published in *Bulletin* 413 of the Astronomical Institutes of the Netherlands in 1950. The two observers recorded their estimates in turn, without communicating with each other, at intervals of less than one minute.



Independent observations of the same 1950 VV Puppis maximum by two astronomers showed minor peaks preceding and following greatest brightness.

The resulting light curves are reproduced here. A total of 56 observations was secured during 35 minutes covering the maximum. The time resolution is therefore much better than can be achieved photographically (some 14 observations per 100-minute cycle) and perhaps not inferior to what can be achieved photoelectrically with a star as faint as magnitude 15 to 17.

This maximum was a bright one. Its peculiar interest lies in the occurrence of *three* peaks, each noted by both observers, for two subsidiary peaks took place some 10 minutes before and after the central maximum. There is some difference in scale between the two observers, despite the use of the same comparison-star sequence, which perhaps is due to the Purkinje effect (change in color sensitivity of the eye at low light levels). But there can be no doubt as to the reality of the two lesser peaks.

There is some evidence of similar subsidiary peaks in the visual light curves of Julian Days 2,433,053 and 2,433,055 (May 16 and 18, 1950) published in *B.A.N.* 413, Fig. 3.

Considered in terms of Herbig's model, the observations imply that the hot spot is subject to variations in time intervals of the order of 10 minutes. He had already suggested some intrinsic changes in the hot patch, to account for alterations in the light curve of VV Puppis.

An alternative hypothesis might be proposed that the peculiarity consists instead of subsidiary *minima,* due to partial eclipses of the hot spot. But this would imply extreme irregularity in the eclipsing body, and would be at variance with Herbig's model, in which the companion star (the eclipsing body) is well out of the way at maximum.

In connection with the secondary peaks, mention should be made of Thackeray's visual observations in 1950 of fluctuations, at intervals of the order of seconds, during several bright maxima of VV Puppis.

P. T. OOSTERHOFF
Leiden Observatory,
and A. D. THACKERAY
Radcliffe Observatory

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 104th meeting of the American Astronomical Society at Cleveland, Ohio, December 27-30, 1959. Complete abstracts will appear in the Astronomical Journal.

Primordial Composition of the Solar System

Theories of the origin and development of the solar system depend on a knowledge of the original composition of the material from which the sun and earth were formed. To attain this, we must first know the present-day abundances of elements — a problem with many difficulties, both observational and theoretical.

A new table of relative abundances was presented by Lawrence H. Aller, University of Michigan Observatory, who adopted the view that the sun's atmosphere represents closely the original composition of the solar system, except for such elements as lithium, boron, and beryllium, which have been destroyed by thermonuclear reactions deep in the solar convection zone. With L. Goldberg and E. Müller, Dr. Aller has recently completed a new quantitative chemical analysis of the sun.

However, a table based on solar abundances alone would contain a number of gaps, for the spectral lines of many elements are either masked by lines of more abundant ones or fall in inaccessible regions of the spectrum. Thus, estimates for elements lighter than the iron group were also based on extensive studies of early-type (*B*) stars and gaseous nebulae. Though we cannot assume that the composition of the Orion nebula, for example, and the stars formed from it is the same as the sun's, there are indications that the abundances of the lighter elements in the interstellar medium have not changed greatly in the last five billion years.

For the heavier elements, we must depend on data obtained from meteorites and the earth's crust. Generally, chondritic meteorites are believed to give the best sample of most nonvolatile elements, but the results are incomplete, particularly for the rare earths.

The general procedure, similar to that used in 1956 by H. E. Suess and H. C. Urey, was to make an initial estimate of the abundance of a certain element from the observational data concerning it. Then isotopes of odd and even atomic numbers were plotted separately and the trends of the curves noted. For several elements these curves suggested revisions in the initial estimates. Dr. Aller pointed out that his compilation is extremely tentative, particularly for the heavier elements.

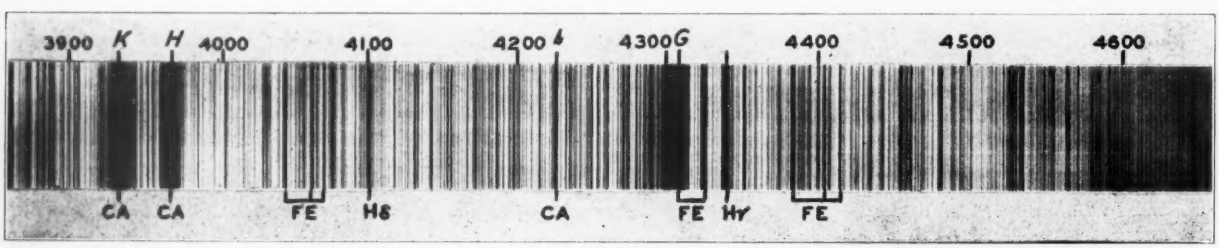
The Michigan astronomer expresses his result for each element by the logarithm of the number of its atoms per 10^{12} atoms of hydrogen. Thus, the value $\log N = 7.50$ he finds for silicon means that there are 32 million atoms of silicon for every million million hydrogen atoms. (The abundance table by A. G. W. Cameron on page 614 of the September, 1959, SKY AND TELESCOPE has a different unit; it gives the number of atoms per 10^6 of silicon.) According to Dr. Aller, the second lightest element, helium, is about one-sixth as abundant as hydrogen.

Values for the elements lighter than potassium (atomic number 19) are based almost entirely on astronomical data. The Michigan astronomer considers some of the best-established points to be those for iron (26) and its associated elements, the strontium (38) group, as well as barium (56). From potassium (19) through nickel (28), the solar and Suess-Urey abundances are in as good agreement as can be expected, with one exception. Iron appears

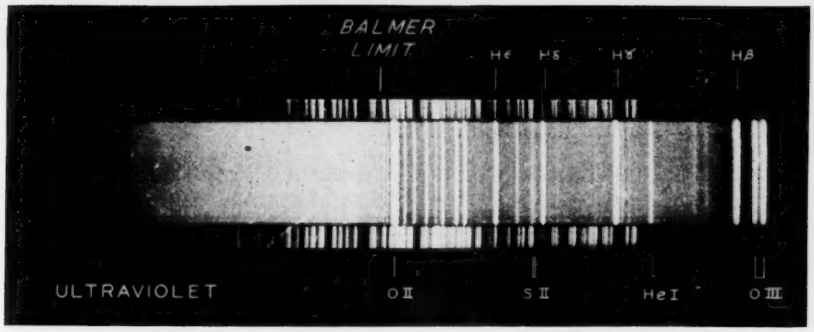
ABUNDANCE SCALE FOR SOLAR SYSTEM

Element	*log N*	*Source*	*Element*	*log N*	*Source*	*Element*	*log N*	*Source*
1 H	12.00	S, O, B	29 Cu	4.50	U, S	58 Ce	1.70	R
2 He	11.21	O, B	30 Zn	4.28	S, U	59 Pr	0.82	R
3 Li	3.50	U	31 Ga	2.45	U, S	60 Nd	1.46	R
4 Be	2.80	U	32 Ge	3.20	U, S	62 Sm	0.85	R, C
5 B	2.88	U	33 As	2.11	U	63 Eu	0.05	R
6 C	8.60	S, B	34 Se	3.33	U	64 Gd	0.78	R
7 N	8.05	S	35 Br	2.65	U	65 Tb	−0.06	R
8 O	8.95	S	36 Kr	3.21	U	66 Dy	0.65	R
9 F	6.0:	B, U	37 Rb	2.35	S, U	67 Ho	0.02	R
10 Ne	8.70	B	38 Sr	2.70	U, S	68 Er	0.33	R
11 Na	6.30	S	39 Y	2.45	U	69 Tm	−0.75	R
12 Mg	7.40	S	40 Zr	2.50	S, C	70 Yb	0.35	R
13 Al	6.22	S, B	41 Nb	1.50	U	71 Lu	−0.40	R
14 Si	7.50	—	42 Mo	1.88	U, S	72 Hf	0.40	C, R
15 P	5.40	S, U	44 Ru	1.44	C, S	73 Ta	0.75	C, U
16 S	7.35	S, B	45 Rh	0.80	U, S	74 W	0.60	C
17 Cl	6.25	O, B	46 Pd	1.26	U, S	75 Re	0.90	C, U
18 A	6.88	O, B	47 Ag	0.82	U, S	76 Os	1.40	C, U
19 K	4.82	S, U	48 Cd	1.45	U, S	77 Ir	1.20	C
20 Ca	6.19	S, U	49 In	0.75	U, S	78 Pt	1.70	C
21 Sc	2.85	S, U	50 Sn	1.57	U, S	79 Au	0.66	—
22 Ti	4.89	U	51 Sb	0.95	U, S	80 Hg	0.75	—
23 V	3.82	U, S	52 Te	2.05	C, U	81 Tl	0.55	—
24 Cr	5.38	U, S	53 I	1.35	C, U	82 Pb	1.06	S
25 Mn	5.12	U, S	54 Xe	2.06	C, U	83 Bi	0.50	—
26 Fe	6.57	S	55 Cs	1.16	C, U	90 Th	0.00	—
27 Co	4.75	U, S	56 Ba	2.08	S, U	92 U	−0.30	—
28 Ni	5.95	U, S	57 La	1.30	R, C			

Source of data: B, *B*-star data; C, Cameron (1959); O, Orion nebula (Liller-Aller, 1959); R, Rankama's data as revised by Ahrens; S, Sun (Goldberg, Müller, Aller, 1959); U, Suess-Urey (1956).



The most completely analyzed sample of extraterrestrial matter is the atmosphere of the sun. Measurements of the intensities of absorption lines in the solar spectrum form a basic source of information regarding the chemical composition of the cosmos. Here is shown a portion of the sun's spectrum from a wave length near 3900 angstroms in the violet to 4600 in the blue. Some lines due to calcium, iron, and hydrogen are labeled. Mount Wilson Observatory photograph.



The Great Nebula in Orion, Messier 42, gives valuable information on the relative abundances of the lighter elements. This spectrogram, with some emission lines labeled for hydrogen, oxygen, sulphur, and helium, was taken with the 82-inch McDonald Observatory reflector by Jesse L. Greenstein. Above and below the nebular spectrum are laboratory comparison spectra from which wave lengths may be calibrated.

to be relatively much less abundant in the sun than in chondritic meteorites. The solar value was adopted. Solar abundances of rubidium and strontium are in fair agreement with the Suess-Urey values, as is also true for barium.

Fortunately, several spectral lines of lead are observed in the sun. At the present time, J. Paul Mutschlecner, of the University of Michigan Observatory, is subjecting them to detailed analysis. But there is a serious difficulty — a marked disagreement between the theoretically calculated and the experimentally determined values of the atomic line absorption coefficients for lead. In Dr. Aller's table on the preceding page, the solar abundance used is on the basis of the experimental value. If, however, the theoretical value is correct, the lead abundance will be increased, and brought more into line with the expectations of nucleogenesis theory.

Major questions involve chlorine (17), copper (29), yttrium (39), and tantalum (73). The chlorine abundance, 1.8 million atoms, obtained from studies of Gamma Pegasi and the Orion nebula, may be too high by a factor of five. Yet the nebular data do not suggest a value for chlorine as low as the one for phosphorus (15), 250,000 atoms. Strong forbidden lines of chlorine are observed in a number of gaseous nebulae, but those of phosphorus have never been detected.

The sun's copper abundance is considerably greater than in the Suess-Urey compilation or in meteorites. A reduction by a factor of three would make a smoother curve, but copper remains an outstanding problem in the solar abundance compilation. Theoretical difficulties cause chaos in the yttrium determinations, spectral lines arising from different energy levels yielding badly discordant results. Possibly the yttrium abundance in the table should be reduced by a factor of five.

The rare earths (atomic numbers 57 to 71) present a perplexing problem. While their relative abundances can be established with some degree of certainty, there seem to be differences between the results from meteorites and those from earth's crust analyses. Some of this discordance may be real, but part may represent poor analyses of the meteorite material. With recently improved techniques the shortcomings may be eliminated. Unfortunately, no solar determinations for these elements are available. Dr. Aller has used rare-earth abundances tabulated from crustal studies by K. Rankama and G. Sahama in 1950, but has had difficulty establishing the zero point of the scale to fit the rare earths into the rest of the table. He pointed out the possibility that the rare-earth abundances may have to be increased.

A reduction of the tabulated tantalum abundance by a factor of 10 would appear reasonable. This element and tungsten, rhenium, osmium, iridium, platinum, mercury, and thallium are not observed in the sun, and gold has not been completely studied. Hence, the terrestrial, meteoritic, and nucleogenesis estimates have to be used.

Dr. Aller thus stressed the elements for which the analyses should be improved, but suggested that we may not solve the riddle of the solar system's primordial composition until actual samples of material from remote parts of the solar system can be analyzed with the aid of space probes.

Coma Berenices Cluster and White Dwarfs

The region of the Coma Berenices galactic cluster (page 331) has been searched for stars that are relatively bright in ultraviolet light, a characteristic of typical white dwarfs. This work was done at the Warner and Swasey Observatory of Case Institute of Technology, where C. B. Stephenson has used the large Schmidt telescope of the Nassau station.

The method of observation was first employed at the Tonantzintla Observatory in Mexico (SKY AND TELESCOPE, June, 1956, page 359) to search for blue objects. Three exposures are made on each field, using suitable filters for the violet, blue, and yellow spectral regions, respectively. Each star on the plate has three images, their relative strengths depending on the color of the star, the white dwarfs being strong in the violet.

Within $2\frac{1}{2}$ degrees of the center of the Coma Berenices cluster, Dr. Stephenson found five such stars, four of them previously known. But he also observed four comparison fields in the sky near the cluster, finding 14 additional stars of this kind. All the bluest stars on Tonantzintla plates of the same regions were confirmed. These combined results indicate no pronounced concentration of bright ultraviolet stars in the direction of the Coma cluster down to photographic magnitude 17.0. Accordingly, Dr. Stephenson concluded that the number of such stars that are members of the Coma cluster is quite uncertain. Apparently there is no strong clustering there, as sometimes supposed.

Intense Solar Flares of July 16, 1959

Two major eruptions of incandescent gas occurred in a region of activity on the north central part of the sun's disk last July 16th. The first, at 15:55 Universal time, was rated as a flare of importance 3. The second, appearing about five hours later at 21:15 UT, was an even greater outburst, a flare of importance 3+.

According to Helen Dodson and E. Ruth Hedeman, who studied the phenomena optically at the McMath-Hulbert Observatory in Michigan, the two flares

Five of the women astronomers attending the meeting in Cleveland were now or formerly associated with Goucher College in Maryland. Left to right: Dr. Sally Dieke, Goucher professor of astronomy; Lynn Hallgren, graduate student at Indiana University; Dr. Helen Dodson Prince, McMath-Hulbert Observatory; Mrs. Harriet Hutzler Malitson, Washington, D. C.; and E. Ruth Hedeman, McMath-Hulbert.

differed significantly in their emission at radio frequencies. Radio astronomy establishments reported that both were accompanied by fast- and slow-drift bursts of strong solar radio noise. (The former kind of burst is characterized by rapidly decreasing frequency, as opposed to the more gradual decline in frequency shown by the latter.)

The principal event detected at a wave length of 10 centimeters in connection with the earlier flare was a burst lasting nine minutes and having a peak flux of 350×10^{-22} watt per square meter per cycle per second. With the second flare, a "great burst" of more than three hours duration and peak flux of $6{,}500 \times 10^{-22}$ in the same units occurred. In addition, the latter event was associated with unusually intense continuum emission at radio frequencies and with enhancement of high-energy particles in the neighborhood of the earth.

Some great flares that appear in the red light of the hydrogen-alpha line are accompanied by this intense continuum radiation, others are not. The present McMath-Hulbert study is part of a more general comparison of optical records of great flares, in the hope of correlating certain flare characteristics with differences in the radio-frequency emission.

Up to the present, no direct connection has been found between differences in flare sizes, brightnesses, times of rise to maxima, and optical spectra, and the radio phenomena in question. On the other hand, in all cases examined so far, there has been a close association between copious centimeter radio emission and the occurrence of Hα flares over the *umbrae* of large sunspots.

This difference in location of flares is well illustrated by those of July 16, 1959. No portion of the earlier one occurred directly over the umbra of a large spot, but during the second flare, which had intense centimeter emission, three large umbrae were covered by the enhanced Hα radiation.

The development and position of the second flare can be seen in the sample spectroheliograms reproduced here. These represent a small part of the McMath-Hulbert Observatory records of this event that were obtained with the 50-foot tower telescope, using a focal length of 40 feet.

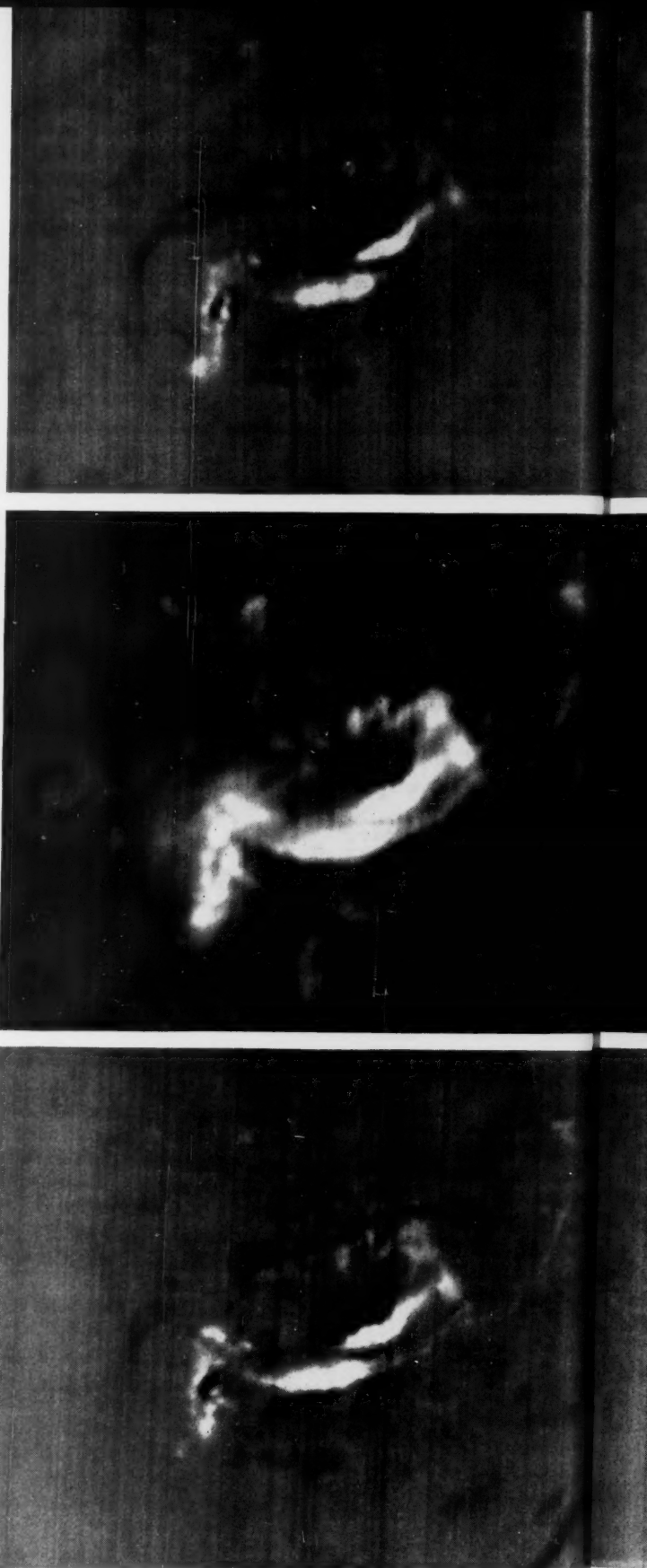
Throughout the flare, series of spectroheliograms were taken at different wave lengths within a six-angstrom interval centered on the Hα line. The three pictures across the top row were obtained in light one angstrom to the violet of the center of the line; those in the middle were centered directly on Hα; while the three in the lowest row were photographed in light one angstrom to the red of that line.

In general, the greatest intensity and extent of the flare is shown by the middle row of pictures. Here the flare appears strong and spread out. Notice that the details on the sun's surface cannot be seen, as light from the center of the Hα line arises in the sun's chromosphere fairly high above the photosphere. By shifting away from the middle of this spectral line, however, a lower level of the solar atmosphere is observed. Thus, the underlying sunspots are revealed in both the top and bottom rows.

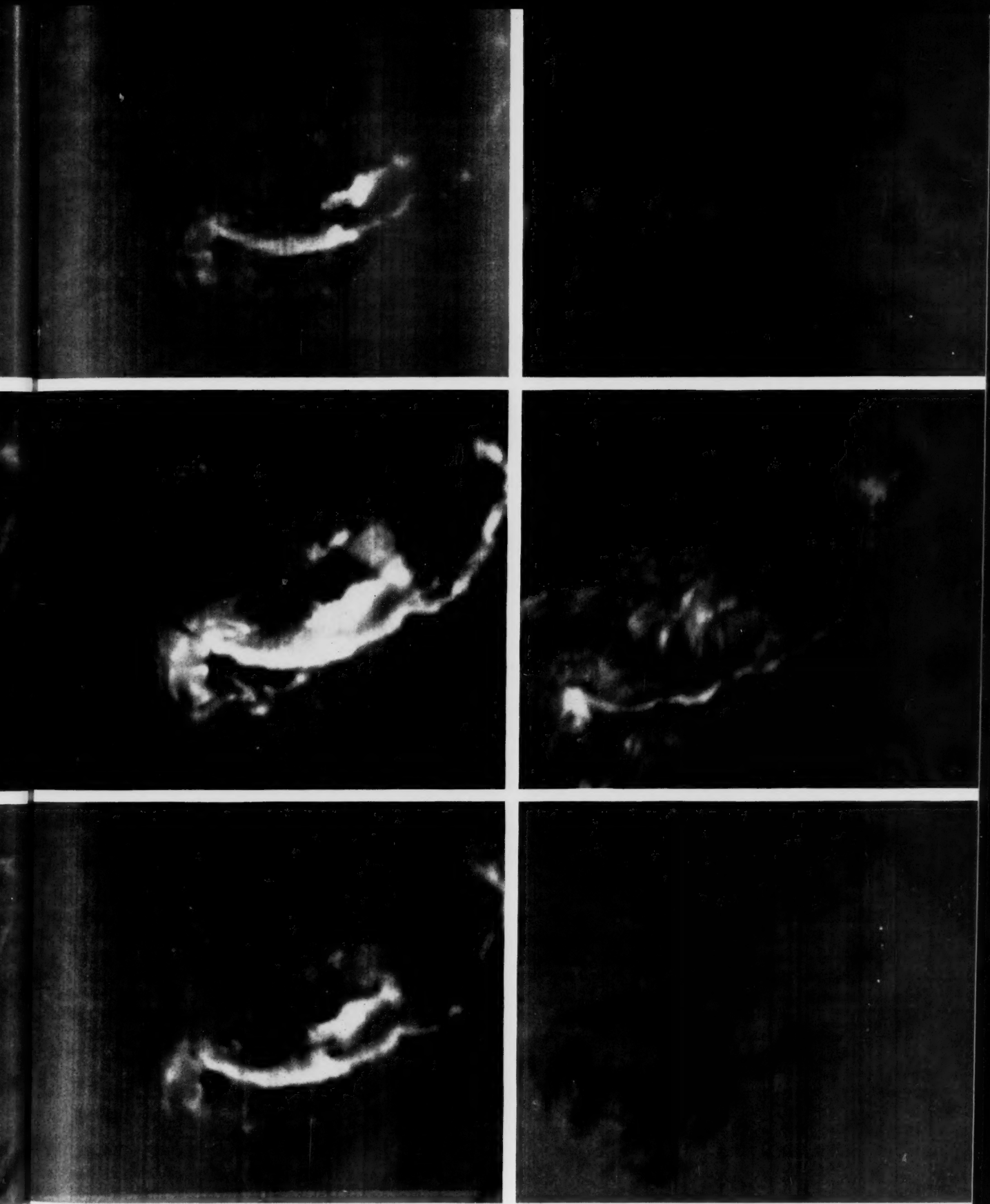
It is by comparing these rows with the middle one that ascending and descending gases can be studied. Features that occur exclusively, or primarily, in the top row represent material with a net outward velocity relative to phenomena in the middle row. That is, this material is rising from the sun, as it is visible in light one angstrom to the violet of the center of the Hα line, and according to the Doppler principle must have a relative velocity of approach.

Similarly, material receding from us, or descending toward the photosphere, is recorded by the one-angstrom red shift used in obtaining the bottom row of spectroheliograms.

Note especially the development of complex descending absorption features late in the course of the flare. The last spectroheliogram taken to the redward of Hα shows this material as an extensive system of curved dark streamers, which may be loop-type prominences seen projected against the sun's disk. This picture was obtained about $1\frac{1}{4}$ hours after the maximum phase of the flare, which is shown in the central column.



Spectroheliograms of a small portion of the sun in hydrogen-alpha light, showing a flare of importance 3+ on July 16, 1959. These were made with the 50-foot tower telescope of McMath-



Hulbert Observatory. From left to right, vertical columns show the flare at 21:25, 21:32, and 22:50 Universal time, respectively. The spectroheliograph slit was shifted one angstrom to the violet of the center of the hydrogen-alpha line for the top row of pictures, and one angstrom to the red for the bottom. Photographs, McMath-Hulbert Observatory, University of Michigan.

ASTRONOMICAL SCRAPBOOK

Visual Star Colors and a List of Red Stars

WHAT is the color of a star? To answer this question, a thoroughly up-to-date astronomer may show you several holes on a punch card, the automatically made record of a photoelectric photometer that has seen the star through different color filters. A generation ago, the astronomer would have evaluated the star's color by photographing it on blue- and yellow-sensitive emulsions, then comparing the magnitudes measured on the two plates. It seems a long time since the colors of stars were determined by simply looking!

In the latter years of the 19th century, many astronomers, professional and amateur, were studying star colors visually. In particular, searching for very red stars was a common occupation. The Irish amateur John Birmingham compiled a list of 658 of them in 1876, which was revised and extended to 766 objects by an English clergyman-astronomer, T. E. Espin, in 1888. When the British Astronomical Association was founded in 1890, one of its observing sections was devoted to stellar colors, and was very active for a few years.

Astronomical fashions can change abruptly, and amateur interest in colored stars is now largely history. There are some visible vestiges of the older period in Norton's *Star Atlas,* which even in its latest editions labels certain red stars by the letter "R," and occasionally gives their numbers in the Espin-Birmingham catalogue.

The stars themselves have not changed, and their hues can still fascinate the amateur who explores the heavens for his own pleasure. Even to the unaided eye, the white of Vega, the orange of Aldebaran, and the red of Antares are conspicuous, and with practice many intermediate hues become recognizable among the 1st- and 2nd-magnitude stars. Fainter objects, however, appear a nondescript gray or a subjective blue, as a rule. But a 3-inch or 4-inch glass will extend a color survey to about magnitude 6, while a 6- or 8-inch reflector is highly effective for picking out red stars in Milky Way fields. The larger the aperture used to view a star, the more distinct and vivid its hue. Reflecting telescopes are better than refractors for this purpose, because they are fully achromatic.

It is still an interesting experiment to spend an evening or two gauging the tints of a number of the brighter stars by inspection, preferably with the aid of binoculars. Certain precautions are helpful. Avoid stray light, which can falsify colors by contrast or fatigue effects. Do not attempt stars too near the horizon, where the atmosphere can cause a spurious reddening.

For the convenience of the amateur who wishes to inspect some red stars, a list of 40 bright representatives is presented here. All of them can be located with the aid of the Skalnate Pleso atlas. The positions are for 1950. Variability in brightness is common among the redder stars, but Mira-type variables have generally been omitted from the list, as special charts are ordinarily needed to identify them when they are faint.

Verbal descriptions of color have their limitations; they are highly personal and often indefinite, and terms like *fiery red* invite exaggeration. It is much better to use a numerical scale for estimating star colors, a proposal first made in 1872, by the Athens astronomer J. F. J. Schmidt.

He explains his idea as follows: "I leave aside the greens, blues, and purples seen only in double stars, as well as the greenish tinge of many single ones, and confine myself to the series which begins at pure white, runs through all grades to yellow, and passes eventually to red. Actually my observations do not show any perfectly white or perfectly red stars. . . . In my scale I set pure white = 0, pure yellow = 4, deep golden yellow = 6, and all of my red stars are graded between 6.5 and 9."

Many slight modifications of the original Schmidt scale were later suggested. The German amateur H. Osthoff, of Cologne, spent 25 years studying star colors visually. For practical use, the definitions of the color steps he proposed in 1912 are helpful:

0 White
1 White with a slight admixture of yellow
2 Yellow and white in equal parts
3 Light yellow
4 Pure yellow
5 Deep yellow
6 Yellow with a slight admixture of red
7 Red and yellow in equal parts (orange)
8 Orange red
9 Red

A good idea of how an old-time color observer of the best class went about his work is given by Osthoff. He describes the systematic estimates of star colors with a 4-inch refractor in preparation of his catalogue published in 1900:

"The observing room was always entirely darkened. I covered my head and the eye end of the telescope with a dark cloth. The observations were written down in the dark, and the color was always expressed in one figure, without decimals. Only under the most pressing circumstances was the lantern opened during the time of observation, and then only to look at the star chart. I always estimated an unknown star with respect to a known star. At the conclusion of

Star	Right Ascension h m	Declination ° ′	Visual Magnitude	Spectrum	Star	Right Ascension h m	Declination ° ′	Visual Magnitude	Spectrum
Z Piscium	1 13.4	+25 30	7.0-7.9	*N*0	VY Ursae Majoris	10 41.6	+67 40	6.0-6.6	*N*0
R Sculptoris	1 24.7	−32 48	5.8-7.7	*N*3	Y Canum Venat.	12 42.8	+45 43	5.2-6.6	*N*3
o Ceti[1]	2 16.8	−03 12	2.0-10.1	*M*6e	TU Canum Venat.	12 52.7	+47 28	5.4-5.9	*M*6
Z Eridani	2 45.5	−12 40	6.4-7.8	*M*4	W Hydrae	13 46.2	−28 07	5.9-9.8	*M*8e
RZ Arietis[2]	2 53.0	+18 08	5.4-5.8	*M*6	X Herculis	16 01.1	+47 23	6.3-7.4	*M*6
ρ Persei	3 02.0	+38 39	3.2-3.8	*M*4	α Scorpii[6]	16 26.3	−26 19	0.9-1.8	*M*1
R Doradus	4 36.2	−62 11	5.3-6.3	*M*7	g Herculis	16 27.0	+41 59	4.6-6.0	*M*6
ST Camelopardalis	4 46.0	+68 05	6.9-8.3	*N*5	α Herculis[7]	17 12.4	+14 27	3.0-4.0	*M*5
R Leporis[3]	4 57.3	−14 53	5.5-10.7	*N*6e	XY Lyrae	18 36.5	+39 37	6.1-6.6	*M*4
W Orionis	5 02.8	+01 07	5.9-7.7	*N*5	S Scuti	18 47.6	−07 58	7.0-8.0	*N*3
RX Leporis	5 09.0	−11 55	5.9-7.0	*M*6	δ[2] Lyrae	18 52.8	+36 50	4.3-4.7	*M*4
CE Tauri[4]	5 29.3	+18 34	4.6-5.0	*M*2	R Lyrae	18 53.8	+43 53	4.0-5.0	*M*5
α Orionis[5]	5 52.5	+07 24	0.4-1.3	*M*4	V Aquilae	19 01.7	−05 46	6.7-8.2	*N*6
η Geminorum	6 11.9	+22 31	3.1-3.9	*M*3	V450 Aquilae	19 31.3	+05 21	6.3-6.9	*M*7
BL Orionis	6 22.6	+14 45	6.3-6.9	*N*	AQ Sagittarii	19 31.4	−16 30	6.6-7.6	*N*3
UU Aurigae	6 33.1	+38 29	5.1-6.8	*N*3	AC Draconis	20 19.9	+68 48	5.2-5.4	*M*5
L[2] Puppis	7 12.0	−44 33	3.4-6.2	*M*5e	W Cygni	21 34.1	+45 09	5.0-7.6	*M*4e
R Leonis	9 44.9	+11 40	5.4-10.5	*M*8e	V460 Cygni	21 39.9	+35 17	6.1-7.0	*N*1
U Antliae	10 33.0	−39 18	5.7-6.8	*N*b	μ Cephei[8]	21 42.0	+58 33	3.6-5.1	*M*2e
U Hydrae	10 35.1	−13 07	4.8-5.8	*N*2	TX Piscium[9]	23 43.8	+03 13	4.9-5.7	*N*0

SYNONYMS: 1, Mira; 2, 45 Arietis; 3, Hind's crimson star; 4, 119 Tauri; 5, Betelgeuse; 6, Antares; 7, Rasalgethi; 8, W. Herschel's garnet star; 9, 19 Piscium.

the observations, still during the night, or at the latest the next morning, I glanced over my notes and identified the stars. Before the beginning of each evening's work I looked over the program, but did not take any heed of the observations already made.

"When there was bright moonlight, unsteady air, or a too cloudy sky, I made no estimation of color. I looked long and fixedly at each star until the impression of its color no longer fluctuated. The average time required for a color estimate was 2.21 minutes."

JOSEPH ASHBROOK

WATER IN VENUS' ATMOSPHERE

Detecting water vapor in the atmospheres of other planets is extremely difficult because of the vast amount of it in our own air. Therefore, last November 29th the U. S. Navy sent a manned balloon to an altitude of 80,000 feet — above 98 per cent of the earth's air — to make spectroscopic observations of Venus.

Analysis of the pen-recorder tracings has now been completed at Johns Hopkins University, and Dr. John Strong, of its Laboratory of Astrophysics and Physical Meteorology, has communicated the following summary of the results:

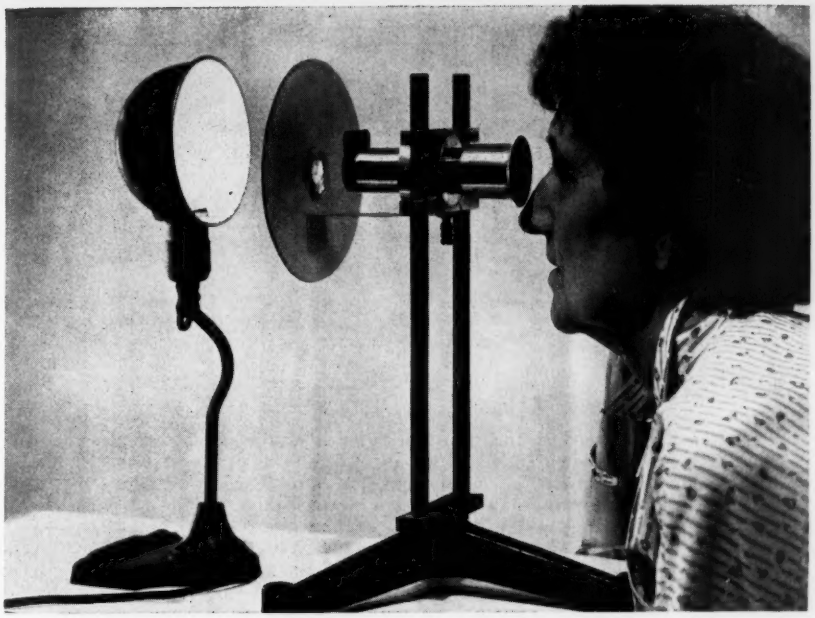
"Commander Malcolm D. Ross (the pilot) and Charles B. Moore (the scientific observer) had difficulties with balloon gondola motion during the half an hour that Venus was available to observation. In spite of this they got three periods during which Venus was studied, and in each of these periods the water lines in the 11,300-angstrom band of H_2O modulated the detector response.

"The average modulation ($5\% \pm 4\%$), using a calibration made in the Stratobowl, and ignoring total pressure corrections, gave 53 microns as the liquid-layer equivalent water vapor penetrated in the atmosphere of Venus. After dividing by 2.8, to account for the double traversal and average path inclination, we get 19 microns as the equivalent liquid water layer above the Venus cloud level.

"If the pressure is less on Venus (as we expect) than it was on the occasion of calibration at the Stratobowl in South Dakota, this modulation would correspond to a higher water content. The increase would be small, unless the pressure is below 0.1 atmosphere, since the modulations were nearly in the linear region rather than the square-root law region. The water vapor in the part of the optical path in the earth's atmosphere above the gondola was negligible.

"The measured Venus water is about four times more water than lies in our own stratosphere (4 microns precipitable water above 48,000 feet over the British Isles), and is about the same as lies above high-level clouds on the earth. . . .

"We presume there is much more water in the Venusian atmosphere below the cloud level."



The grating spectroscope described in Ernst Keil's article is shown here being used in a laboratory test of the properties of a filter. Next to the light source is a condensing lens, and the filter is mounted at the tube end next to this, covering half the slit length. This spectroscope will also fit directly into the eyepiece holder of a telescope. Photograph by the author.

A Simple Replica-Grating Spectroscope

ERNST KEIL

WHY have so few amateur astronomers tried their hand at that fascinating branch of astronomical science, spectroscopy? Nowadays much of the work at large and small observatories around the world is spectroscopic. This neglect on the part of the amateur is hard to explain, for anyone who has the skill and patience to make, mount, and adjust a first-rate mirror or lens is surely qualified to make the simple spectroscopic equipment that suits his needs.

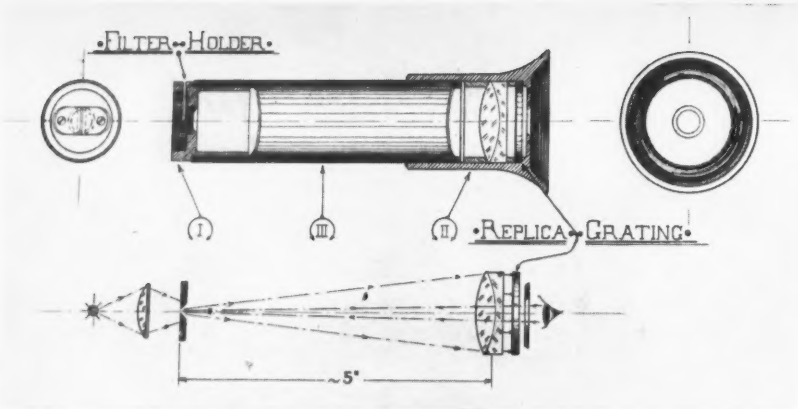
Though the amateur's field of activity will be more restricted than the professional's, that is no reason why he should deprive himself of the keen satisfaction he can derive from his efforts in spectroscopy. A famous American physicist and astronomer, A. A. Michelson, once said during a lecture on light: "This to my mind is one of the most fascinating departments not only of science but of human knowledge. If a poet could at the same time be a physicist, he might convey to others the pleasure, the satisfaction, almost reverence which the subject inspires. The aesthetic side of the subject is, I confess, by no means the least attractive to me."

In the radiations reaching us from the sun and other stars, each element produces lines with characteristic wave lengths, and can make its presence known by their definite color and position in the spectrum. But it requires a spectroscope to make visible to the eye the splendors of the spectral colors, and to arrange in orderly sequence the multitude of light waves.

An amateur's spectroscope for exploring the simpler aspects of spectra should be designed for convenient visual use. By inserting the instrument in the eye end of a telescope, he can observe such celestial objects as the sun and brighter stars, and demonstrate that the moon shines by reflected solar light. The device can be used for many experiments on the ability of filters to restrict the passage of particular wave lengths or colors, and for the investigation of other interesting phenomena.

The instrument should be simple mechanically and optically, yet conform as nearly as possible to scientific standards. Its construction should allow it to be hand held, attached to a telescope, or mounted on a suitable support for laboratory experiments. These requirements are best met by a direct-vision spectroscope, equipped with a transmission-type replica grating. This apparatus consists of the grating and one lens, the latter serving both for collimating and viewing.

The use of a replica grating as the dispersing element, instead of one or



The author has sketched the construction of the direct-vision spectroscope, whose optical parts are a single achromatic lens and a replica grating. In the lower section is shown the laboratory setup, with an auxiliary lens for concentrating the light-source beam upon the slit. At the upper left is a front view of the slit assembly.

more prisms, presents conspicuous advantages. A basic objection to prisms is that they disperse red light less than light of shorter wave lengths; a grating, on the other hand, produces a *rational* spectrum, whose uniform wave-length scale facilitates calibration. Furthermore, with prisms, the larger number of optical elements complicates construction and calibration of a spectroscope.

Our instrument, as the accompanying diagram shows, consists of a unit **(I)** for carrying the slit; a housing **(II)** for the replica grating and lens; and a piece of brass tubing **(III)** for alignment of the other two parts. This tube facilitates the two important adjustments of the spectroscope: bringing the slit jaws into sharp focus in the focal plane of the lens, and making them parallel to the lines of the grating.

As in any spectroscope, the spectral lines observed with this instrument are merely images of the slit, distributed according to their respective wave lengths. Thus, the more perfect the edges of the slit, the better defined and sharper the spectral lines will appear. For best performance, the jaws should be made of steel, preferably hardened, and lapped and polished until their edges show not the slightest roughness when viewed through the instrument's collimating lens.

In the diagram of the spectroscope, the slot which holds the filters can be seen in front of the slit. For filter testing, the bottom of the slot should be cut just deep enough for the filter to cover only half the length of the slit, allowing a beam of light to pass unobstructed through the lower half of the slit. In this way, two spectra are formed, one above the other, and can be readily compared. The lower is the normal spectrum of the light source, while the upper is the same spectrum minus the portion blocked by the filter.

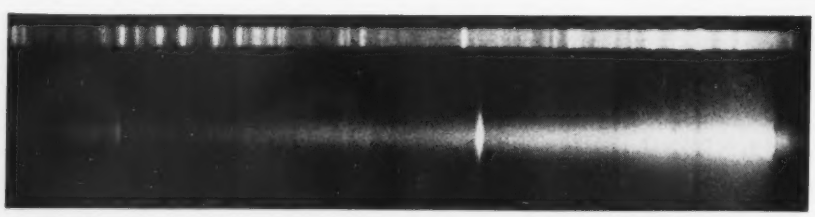
This experiment with filters is best carried out in the laboratory, with the spectroscope held in a suitable support. Place the light source close, to give an intense beam of light on the grating and produce a brilliant spectrum. As shown, we can increase the intensity of the beam by mounting a short-focus condensing lens to concentrate a bright spot of light on the slit. In a similar way, the effectiveness of the spectroscope used with a telescope depends greatly on the telescope's light-gathering power.

A grating (or its offspring, a replica grating) is the heart that makes most of our present-day spectroscopic equipment live. Reproduced here is a close-up view of a remarkable scientific achievement, a photomicrograph of a tiny section of a diffraction grating that has 15,000 grooves per inch, ruled on speculum metal. The grating is six inches wide, with 90,000 such grooves, each four inches long.

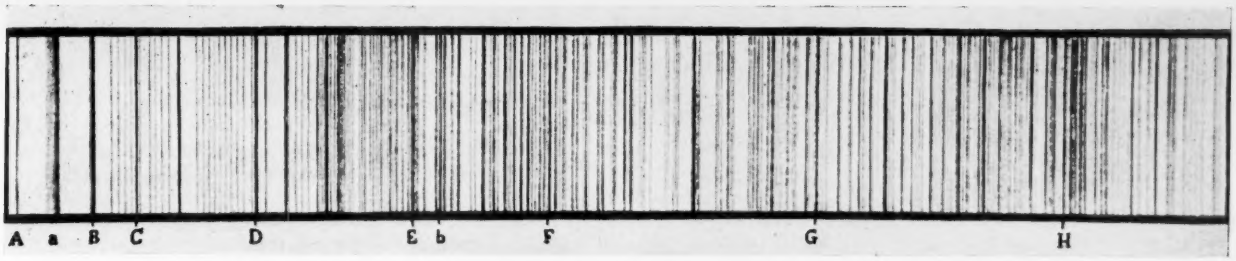
The accuracy requirements of such a grating are breathtaking. The surface in which the grooves are to be cut must be flat within 1/50 wave length of light, and the grooves must be straight, parallel, and evenly spaced, with no spacing error greater than 1/1,000,000 inch.

Soon after H. A. Rowland, at Johns Hopkins University, finished ruling his first grating on a speculum-metal blank some 70 years ago, the idea arose of making copies of these marvelous but costly devices. Ever since, the optical world has been interested in the difficult art of producing replica gratings that would have all the precision and perfection of their masters.

To show the perfection and precise spacing of the grooves cut by the ruling engine, this is an enormous enlargement of a small part of a diffraction grating ruled on speculum metal. There are eight lines per inch in the picture, but 15,000 to the inch on the original grating, here magnified nearly 1,900 times. Grating and photomicrograph are by Harold D. Babcock.



Bright comets are interesting subjects for amateur observations by means of a direct-vision spectroscope attached to a telescope. The spectrum of the comet's head normally has bright bands superimposed on a continuous background of reflected sunlight. In rare cases, when comets pass very near the sun, their spectra show bright lines of iron and other metals. This spectrogram of Comet 1957d, taken August 6, 1957, by Theodore Stecher, is noteworthy for the strong yellow emission line of sodium, just to the right of center. University of Michigan Observatory photograph.

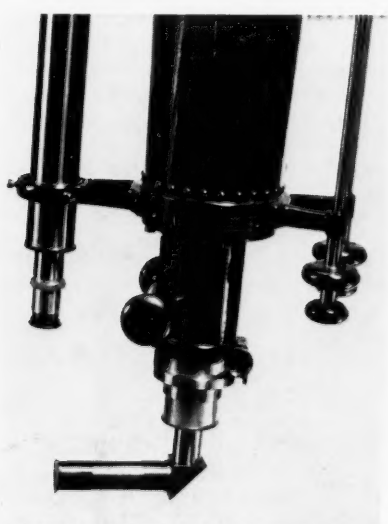


A copy of Fraunhofer's original map of the solar spectrum (1815). Contrary to modern convention, red is at the left, violet at the right. The letters assigned to the stronger lines by Fraunhofer are still in universal use. The two features labeled A and B are absorption bands caused by molecular oxygen in the terrestrial atmosphere; C is the red hydrogen-alpha line.

The original method of making replicas — pouring collodion casts of the ruled surface — long remained essentially unchanged, though materials and techniques varied. In recent years, however, some radically new successful processes have been developed in the United States, and the replicas now available from commercial manufacturers are quite suitable for use in the direct-vision spectroscope we have described here.

This particular spectroscope is equipped with a new-type replica prepared by a method developed by the author. It is 32 millimeters in diameter and has 15,000 lines to the inch, concentrating most of the light in the first- and second-order spectra. In spite of its small size, its performance is excellent, and the dimensions of replicas made by this method are limited only by the size of the master grating.

A novel feature of this replica is that it was produced upon a glass backing, line-side up. Thus, the replica grating can be used for transmitted light, or if aluminized, for reflected light. The aluminum coating may readily be removed without injuring the delicate grooved film of the replica.



For observing celestial objects, the author's spectroscope is attached to a 7-inch refractor that is equipped with a zenith diagonal.

Replicas of this kind allow a considerable simplification of the conventional arrangement for spectroscopic work with transmitted light (collimating telescope, replica mounted on glass, and observing telescope). The replica film can be generated directly on the flat surface of an achromatic plano-convex collimating lens, thus eliminating the need for a separate support. The replica film formed on the collimating lens becomes for all practical purposes an integral part of the lens, and though it will not peel off, it can be removed without risk to the lens.

It is difficult to evaluate definitely the resolving power of our small spectroscope. Of paramount importance are the construction and adjustment, especially of the slit jaws. The light-gathering power of the telescope and the quality and magnifying power of the collimating lens are likewise of considerable importance. The instrument pictured here just separates, in the second order, the two yellow lines in the mercury spectrum (at wave lengths 5791 and 5770 angstroms). It is equipped with the replica and plano-convex collimating lens combination described above, and was made with particular care for demonstration purposes.

QUESTIONS... FROM THE S+T MAILBAG

Q. Would an 8-inch plate-glass mirror perform suitably in a 5-inch f/2 Schmidt camera?

A. Although its coefficient of expansion is three times that of pyrex, plate glass will make a satisfactory mirror in a Schmidt camera system that is completely enclosed during operation, preventing sudden temperature changes from seriously affecting the mirror's figure. However, sizable temperature differences may change the position of the focal surface, so a calibration chart is necessary for correctly setting the focus according to the temperature at various seasons of the year.

Q. Who was the first person to detect a lunar rill?

A. The Dutch astronomer Christiaan Huygens detected the Hyginus rill in 1684, using a nonachromatic refractor of 60-foot focus and powers of 180 and 160.

Q. What is the least separation at which double stars have been discovered by direct telescopic inspection?

A. R. G. Aitken found a few pairs as close as 0.09 second of arc (for example, Kappa Ursae Majoris) with the Lick 36-inch refractor. Still closer pairs have been found by interferometer observing techniques.

Q. What are the *nubeculae*?

A. *Nubecula major* is an old name for the Large Magellanic Cloud, *nubecula minor* the Small.

Q. What is the phase angle of a planet?

A. It is the angle at the planet between the earth and sun. When the phase angle is divided by 180°, the result is the fraction of the planet's earthward hemisphere that is unilluminated.

Q. What is the faintest star that has been seen with the 40-inch Yerkes refractor?

A. This may have been the observation of the variable star V Delphini by J. A. Parkhurst in August, 1901, when it was magnitude 17.1.

Q. Was Sirius actually a red star in classical times?

A. Practically all recent authorities agree that this former belief is the result of misunderstanding the ancient literary references to this star. Sirius is a white star, of spectral class *A*.

Q. What is the next year when we will twice have two full moons in one month?

A. This infrequent coincidence will take place in 1961: January 1st and 31st, April 1st and 30th.

Q. What is the *epoch* of a star chart?

A. It is the date for which the positions of the stars are plotted on the chart, for example, 1950.0. Due to precession of the equinoxes (westward along the ecliptic), the celestial equatorial co-ordinates are continually shifting with respect to the stars. Thus a star atlas becomes less convenient to use several decades after its epoch. Most charts now in use are drawn for the beginning of 1950, including the monthly maps in this magazine.

W. E. S.

OBSERVING THE SATELLITES

The "Unknown" Satellite

WIDESPREAD public interest was aroused by a Department of Defense announcement on February 10, 1960, that an artificial satellite of unknown origin was circling the earth in a near-polar orbit.

According to Pentagon spokesmen, the mysterious body was first detected on February 1st, by SpaSur, the space surveillance system operated by the Navy for the Advanced Research Projects Agency. This system has two 50-kilowatt radar transmitters in Arizona and Alabama, each with stations to receive 108-megacycle echoes, which are analyzed interferometrically. A search of earlier records at the SpaSur Operations Center at Dahlgren, Virginia, then showed that the strange satellite had been recorded at least as far back as December 19th, and that its orbital elements were inconsistent with those of any recognized artificial moonlet.

The next information made public was a February 11th Pentagon announcement of orbital data, and on the 15th the Air Force's Space Track issued its first ephemeris. Further study led to a Department of Defense statement on February 23rd that the strange object was "most probably the recovery capsule of Discoverer V." This polar satellite had been launched from Vandenberg Air Force Base, California, last August 13th (Sky and Telescope, October, 1959, page 675).

Hence the proper designation of the observed object is 1959ε2. There had been confusion in nomenclature, some reports referring to it as 1960α, a name now withdrawn and reserved for the first successful launching in 1960.

Re-analysis of early records has shown that the SpaSur network had received radar echoes from the capsule as early as August 15, 1959, the day after the capsule was separated from its carrier rocket, and the first date on which any radar contact could have been made from the continental United States. The strength of the signals was consistent with the size of the tub-shaped satellite, about 33 inches in diameter and 27 inches deep.

From the orbital data published by Space Track, it is possible to find substantiating evidence for the identification, and to reconstruct what probably occurred when the capsule separated. Telemetry reports gave the time of separation as 21:42 Universal time on August 14th. This took place over the Pacific Ocean, at latitude 43° north, longitude 165° west. The carrier rocket, just before separation, was traveling about 25,950 feet per second, at a height of about 145 miles, dropping gradually in a path inclined about half a degree to the horizontal, as it approached its 135-mile perigee height. The direction of motion was about 13.6 degrees east of south.

The recovery scheme adopted for the Discoverer series depends critically on the stabilized orientation of the orbiting vehicle, and it is this part of the experiment that seems to have gone wrong. The entire Agena second stage was intended to be traveling tail first, stabilized by gas jets so that the capsule would be pointing backward and 60 degrees below horizontal. The procedure called for the firing of a set of explosive bolts at a predetermined time, allowing springs to push the capsule away from the Agena, and then the retro-rocket in the capsule was to be triggered. The free capsule would then descend, to be snatched in midair by waiting planes.

Instead, it can be deduced from the recently determined orbit of the capsule that at the moment of separation the Agena was traveling nearly nose first, yawed at an angle of perhaps 32 degrees eastward to the line of flight, and probably pointing slightly upward. Thus, the firing of the retro-rocket *increased* the speed of the capsule by about 1,120 feet per second, and changed its direction of motion about 1½ degrees, as projected on a horizontal plane. The calculated increase in velocity is consistent with the known thrust of the retro-rocket and the 195-pound weight of the capsule.

This reconstruction is based on the orbital inclination of 78.94 degrees announced for 1959ε2 by Space Track, and on an initial revolution period of 109.2 minutes for the capsule, extrapolated from the 104.0-minute period on February 25, 1960. By the application of perturbation theory, the regression rate of the nodes of the capsule's orbit can be related to the rate of period change. This gives a total change in the node of more than 220 degrees between the date of separation and February 25th, in excellent agreement with observation.

There are other checks on the identification. The orientation of the orbital plane of 1959ε2, when extrapolated back to the date of separation, agrees reasonably well with the orientation of Discoverer V's orbital plane at that time. Similarly, the position of the perigee point of 1959ε2 can be shown to have been near the separation point, but probably slightly behind it, thereby suggesting that the Agena was tilted upward when the capsule was ejected. Taken together, these facts argue strongly for the identity of the newly found object with the Discoverer V capsule.

The capsule's perigee height was about 130 miles on February 25th. Immediately after its separation from the rocket vehicle, its apogee distance was about 1,360, but it had fallen to 1,050 miles by February 25th. The argument of perigee on the later date was 21.8 degrees, decreasing 2.56 degrees per day.

At the epoch of separation, the local mean time of passage through the ascending node (northward across the equator) was 23:19, but it came earlier by about 8.3 minutes per day, sweeping completely around the clock by February 25th. It was then 19:40, decreasing about 8.75 minutes per day.

The conditions of visibility of polar-orbit satellites were discussed in this department for March, 1959, page 260. In the case of 1959ε2, observers in middle latitudes had two periods of visibility in the morning sky and two in the evening, prior to the radar recognition of this object. At the time of discovery, another period of visibility was commencing in south temperate latitudes. On February 17th, two days after the Space Track ephemeris was distributed, Australian Moonwatch teams at Adelaide and Elizabeth Grove made successful optical observations. A few hours later, there was an additional sighting by the Moonwatch group at Pretoria, South Africa, and the Baker-Nunn camera located nearby obtained photographs. Shortly thereafter, 1959ε2 was also filmed by Baker-Nunn cameras in Argentina and Australia.

Visual observers in February found that the Discoverer V capsule appeared about magnitude +7 when viewed at a range of 500 miles. It would be appreciably brighter for a watcher directly beneath it at perigee. The next period in which optical observations will be possible from the United States comes in late spring.

Satellites in Orbit — March 1st

FROM its improved computation and communication facilities, dedicated in February at Bedford, Massachusetts, the National Space Surveillance Control Center (Space Track) has released the following data concerning the principal satellites in orbit on March 1, 1960:

Satellite	*Period (min.)*	*Apogee (statute*	*Perigee miles)*
1958α	108.7	1,242	216
1958β1	138.2	2,684	402
1958β2	133.8	2,446	405
1958δ2	91.5	354	109
1959α1	122.5	2,050	347
1959α2	129.6	2,279	347
1959ε2	103.9	1,041	125
1959η	129.8	2,325	315
1959ι1	101.2	672	346
1959ι2	101.2	671	343
1959λ	92.2	427	108

The center, operated for the Advanced Research Projects Agency by the Air Force, is responsible for the surveillance of all artificial satellites, and the orbital elements and ephemerides it computes are widely distributed.

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

AAAS Astronomy Highlights

JOHN B. IRWIN
Goethe Link Observatory, Indiana University

Examples of the two types of lunar "seas" discussed at Chicago by G. P. Kuiper can be seen in this Mount Wilson photograph with the 100-inch telescope. Mare Imbrium, covering the whole central part of the picture, is mountain fringed and contains some submerged craters, including Wallace. The latter is centered about 1⅛ inches from the top of the picture, northwest of Eratosthenes. Compare Mare Imbrium with irregularly shaped Mare Frigoris, lower left, and Sinus Roris, lower right. Mount Wilson and Palomar Observatories photograph.

NEW FINDINGS about the planets, moon, and meteorites were presented at Chicago, Illinois, on December 26, 1959, when Section D (Astronomy) of the American Association for the Advancement of Science held a well-attended meeting.

In addition to a morning symposium on solar system problems, co-sponsored by the American Astronautical Society, there was a two-part afternoon conference on photoelectric photometry, the second portion emphasizing work by amateurs and arranged jointly with the Astronomical League. The one-day program also included the address of the retiring vice-president of Section D, given by Dirk Brouwer, director of Yale University Observatory, on problems of positional astronomy in the Southern Hemisphere.

HISTORY OF THE LUNAR SURFACE

"The lunar surface shows a bewildering amount of structural detail, which bears testimony that it has had an eventful history," said G. P. Kuiper, of Yerkes and McDonald Observatories. "Since the moon has no atmosphere now and has almost certainly not had one except possibly during its formative stage, we conclude that erosion as known on the earth is absent from the moon, and that the observed structural features are the accumulative effect of the entire lunar history. On the basis of what is known or inferred about the ages of the earth, the meteorites, the sun, and the solar system, the duration of the lunar history is estimated to be between five and six billion years. On the basis of what is known regarding the meteorites and the earth, it is further estimated that the moon went through a period of widespread internal melting and subsequent freezing about 4.5 billion years ago. This expected development provides a clue to the understanding of many events that appear to have taken place on the lunar surface, including the formation of the maria, the most prominent features. . . ."

Dr. Kuiper pointed out that there are two distinct varieties of lunar maria. The more numerous class, of which Mare Crisium is an example, is essentially round and symmetrical, and surrounded by mountain arcs. These maria have peripheral tension rills and pressure ridges, but contain no ghost (partially drowned) craters. Additional cases are the seas Imbrium, Serenitatis, Nectaris, Smythii, and Humorum. Such maria resemble giant impact craters, as R. S. Baldwin and others have pointed out. Dr. Kuiper believes that these impacts occurred while the moon's interior was near the melting point, and locally probably molten. Hence a mare of this kind should have a genuine lava surface, whose topmost layer has been pulverized by countless minute meteoritic particles over the ages.

Mare Tranquillitatis and Mare Nubium are instances of the second kind of lunar sea, characterized by the absence of fringing mountain arcs and by the presence of ghost craters. While such maria may have rills along their edges, their surface ridges appear to be of local origin, and not related to the general geometry of the mare. The relatively few maria in this class are described by Dr. Kuiper as the result of flooding rather than impact.

"The moon does not appear to be unique in possessing major maria," the Yerkes and McDonald astronomer continued. "The other accessible small planets, Mercury, Mars, and the Jupiter satellites I-IV, also are spotty, much like the moon. This finding strengthens the belief that the impacts were not the main cause of the lavas; the numerous small lava basins on the moon and high-level upwellings of lava, such as in Wargentin, add further evidence. By contrast, large impact craters such as Clavius (150 miles in diameter) show no trace of melting; Clavius is nearly invisible at full moon. The explanation is that Clavius is distinctly pre-mare. Nor do distinctly post-mare craters show any evidence of melting: Copernicus, Tycho, Langrenus. The melting at the surface appears to belong to a rather sharply defined period, which, by analogy to the meteorite data, is assumed to have occurred about 4.5 billion years ago."

ARGON IN STONY METEORITES

The University of Chicago chemist Edward Anders has deduced that the mean temperature of stony meteorites during the major part of their history was a surprisingly low 188° Kelvin at most. His argument is the following.

Measurements of such meteorites' argon-40 content, formed by the radioactive decay of potassium 40, have given 4.0 to 4.4 billion years as the time elapsed since the objects became cold enough to retain the gas. Other methods, based on the decay of uranium and rubidium, indicate that solidification occurred about 4.5 to 5.5 billion years ago.

From the close agreement of the two kinds of dating methods, Dr. Anders suggests that the total argon loss since solidi-

fication has been no higher than 20 per cent and was possibly much lower. This loss could have occurred either during the initial cooling of the meteorite parent bodies, if this process took as long as several hundred million years, or by slow diffusion at low temperatures throughout a meteorite's history.

For the latter case, Dr. Anders made use of experiments (by J. Geiss and D. Hess) in which meteorite samples were heated to various temperatures and the rate of argon expulsion measured. From their results, the stony meteorites' average temperature was found to be 188° as an upper limit. This indicates that the parent bodies must have remained at more than Mars' distance from the sun, as otherwise solar heating would have raised the internal temperature too high.

This result gives strong support to the suggestion that the stony meteorites are products of the breakup of bodies with the dimensions of asteroids rather than planets. Dr. Anders demonstrated this with calculations showing that only in the interiors of parent bodies not larger than 250 kilometers in diameter would radioactive heating be small enough.

Astrometry in the Southern Hemisphere

In his address to Section D, Dr. Brouwer discussed some consequences of the fact that the world's observatories and astronomers are strongly concentrated in the Northern Hemisphere. This unbalance, which leaves the southern skies less well studied, is harmful to observational astronomy, and special measures are necessary to overcome it.

He cited four of the major efforts American observatories have made in the past. In 1890, E. C. Pickering established a Harvard southern station at Arequipa, Peru, which made possible the completion of large programs of star magnitude measurements, the *Henry Draper Catalogue* of spectral types, and numerous surveys of southern galaxies. This station was moved in the 1920's to near Bloemfontein, in South Africa, where it still operates as the Boyden Observatory.

Six decades ago, W. W. Campbell sent a Lick Observatory expedition to Santiago, Chile, with the result that our knowledge of the radial velocities of naked-eye stars is reasonably complete over the entire sky. The third case is Yale University Observatory, which in the 1920's established a station at Johannesburg, South Africa, and shared with the Royal Cape Observatory the amassing of distance measurements of southern stars. The Yale station is now in Australia. About the same time, the University of Michigan established an observatory at Bloemfontein, where R. A. Rossiter and his assistants made a very substantial contribution in the discovery and measurement of southern visual binaries. This list could be extended, of course, by the addition of European and other American astronomical efforts in southern latitudes.

Nevertheless, observational astronomy in the Southern Hemisphere is lagging far behind that in the Northern. A notable exception is the work of the radio astronomers at Sydney, Australia. We are all too familiar with gaps of many kinds in our knowledge of the third of the Milky Way that is unobservable from Europe and North America. Thus, Dr. Brouwer emphasized that Southern Hemisphere observatories are not a mere luxury.

Today the situation in Southern Hemisphere astrometry is alarming, for the Cape Observatory is the only one below the equator now making fundamental determinations of star positions. This makes it practically impossible to provide adequate checks on possible systematic errors in the positions and proper motions of southern stars. When H. R. Morgan compiled his recent Washington$_{30}$ system of star places, six of the 13 southern catalogues from 1910 to 1945 he used were observed at the Cape. However, La Plata Observatory in Argentina is developing a new station for positional work, and the U. S. S. R. Academy of Sciences is considering an expedition to make fundamental observations of southern stars. There are also plans for new astrometric facilities at Caracas, Venezuela.

Meanwhile, some 13 northern observatories are co-operating to produce a new catalogue, known as the AGK$_3$, which should markedly improve our knowledge of proper motions in the northern sky. Although the positions of more than 200,000 stars are to be derived from plates taken with wide-angle cameras, these will depend on the places of some 20,000 reference stars, between declinations +90° and −5°, which will have to be observed visually.

Previously, the bottleneck in such a huge program of cataloguing stars photographically was in the measurement of the plates and in the computations. This is no longer true. Fast automatic measuring engines and electronic computers will make the task far simpler than it was 25 years ago. When the AGK$_3$ is completed, there will be serious consideration of its extension to southern skies.

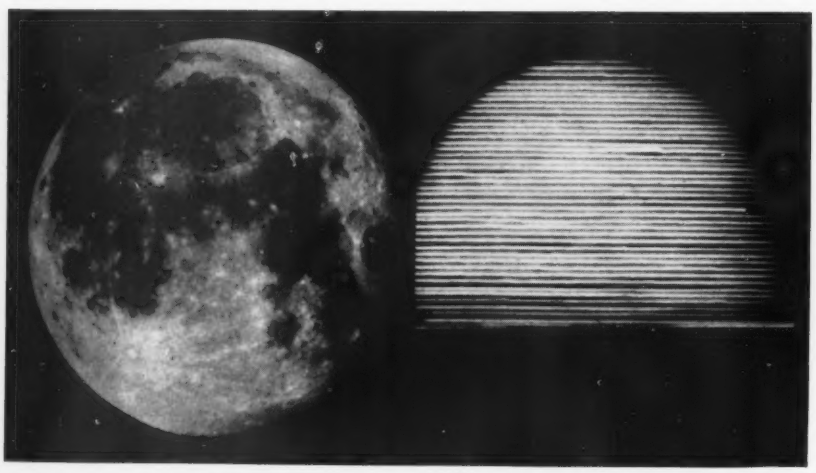
Dr. Brouwer called attention to a program begun at Lick Observatory in the 1930's by W. H. Wright, with the 20-inch Carnegie astrographic refractor. In this project, the positions of stars are tied to distant galaxies, which provide a stable reference network against which absolute proper motions of stars can eventually be determined with great precision. At Lick Observatory, the first-epoch photographs were all taken by 1954 (Sky and Telescope, August, 1954, page 335), covering the sky from the north pole to declination −23°. Second-epoch plates are to be completed about 1985.

It is clear that the final solution from these observations would be much stronger if it covered the entire sky, rather than only three-quarters of it. Dr. Brouwer stated that for this reason Yale Observatory is actively interested in erecting a similar 20-inch astrograph in the Southern Hemisphere.

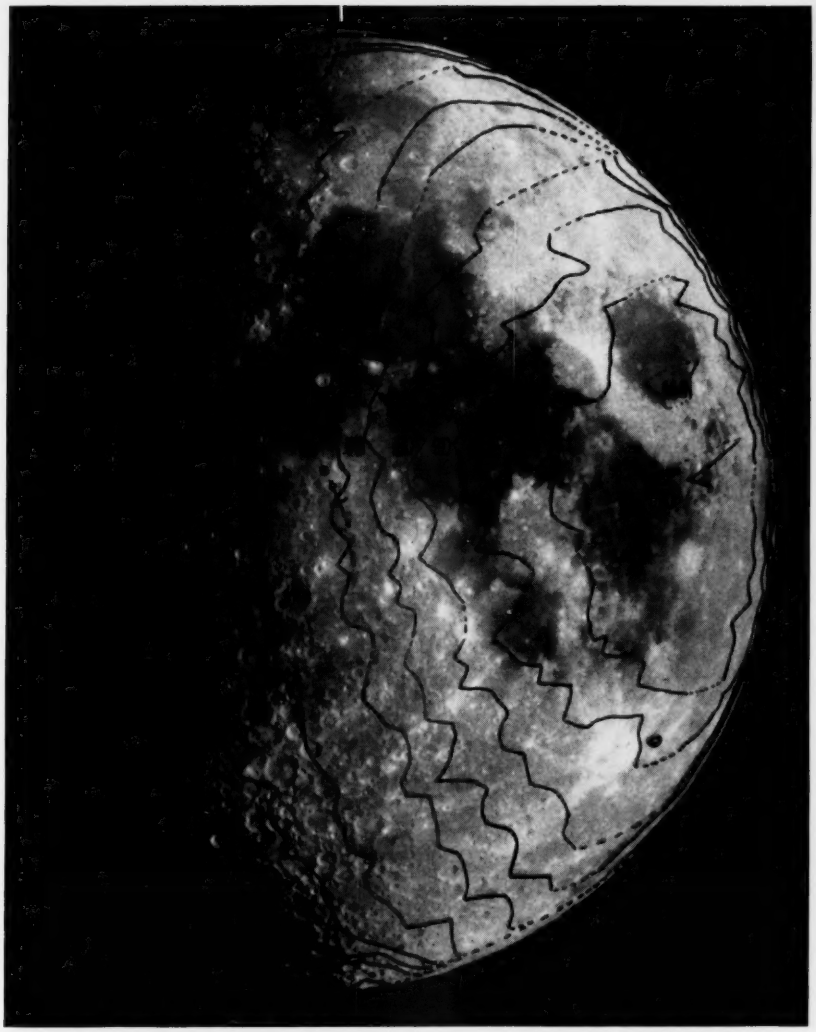
Heat Maps of the Moon

At Lowell Observatory, William M. Sinton, assisted by Ann Geoffrion and Marjorie Korner, has charted the temperature of different parts of the moon's surface, at about 10 different lunar phases. He used the 42-inch reflector with a Golay cell and infrared filters to record the moon's radiation in a narrow band at a wave length of 8.8 microns. To calibrate the measurements, he used artificial sources of black-body radiation, controlled to 0.1 degree centigrade.

The moon was scanned in the manner of television pictures. Dr. Sinton allowed the moon to drift repeatedly through the field of the telescope. Scans were separated by the moon's motion in declination. With this method, possible only on nights when the lunar declination was



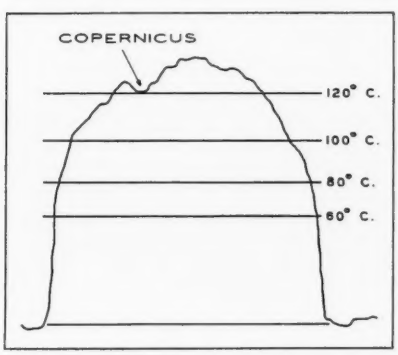
The manner in which the moon was scanned for William Sinton's infrared survey is illustrated. Lowell Observatory picture.



In this Sinton heat map of the moon, lines of equal temperature (isotherms) are labeled in degrees centigrade. Mare Crisium (upper right) is about 110°C. at its southern end. Lowell Observatory chart.

changing rapidly, he could cover the entire moon with 60 horizontal scans in three hours, the scans being made at three-minute intervals.

From the records on each night, a thermal contour map could be constructed of the illuminated part of the moon. The dark side was too cold to allow mapping, but Dr. Sinton was able to confirm the "midnight" temperature of −148° C., derived many years ago at Mount Wilson Observatory by E. Pettit and S. B. Nicholson.



Dr. Sinton's thermal scan through the lunar crater Copernicus shows its cool interior and warm sunlit rim.

The actual temperature at any point on the moon depends on factors that include the angle of incidence of the solar rays and the surface roughness. For a crater near the moon's terminator, the sunlit rim is warmer and the interior colder than the surrounding plain. Dark regions are generally warmer than bright ones, with the result that a "heat picture" of our satellite would somewhat resemble a photographic negative.

The Lowell Observatory astronomer noted, however, that the subsolar point of the lunar surface appears cooler when it is near the east or west limbs than when at the center of the disk. This is explained by the surface roughness, and indicates that at the subsolar point valleys are warmer than peaks, according to Dr. Sinton.

Radio Emission of Planets

As a rule, the planets observed so far by radio techniques have given surprising results, reported Frank D. Drake, National Radio Astronomy Observatory. Only Mars radiates as had been predicted. The weak radio emissions from planets are difficult to study, in the case of Venus being a thousand times weaker than the noise background. Only this planet's disk as a whole can be observed. The radiation in question is not simply reflected solar energy.

Dr. Drake has observed Venus at a wave length of 3.75 centimeters with the 85-foot radio telescope at Green Bank, West Virginia, confirming earlier results by the Naval Research Laboratory in 1956 and 1958, at wave lengths of three and 10 centimeters. He concludes that the planet's surface temperature has remained nearly 585° Fahrenheit for at least the past three years. This is much hotter than the optically determined temperature, which presumably refers to levels high in the atmosphere of the planet. Dr. Drake believes that all water must have evaporated from Venus' surface, forming vapor in its atmosphere. Since liquid water is thus absent because of the high temperature, it is very unlikely that life exists on Venus.

As Venus passed through inferior conjunction in 1956, 1958, and 1959, there were slight variations in temperature. Theoretically, an analysis of these variations could reveal whether the planet's rotation is direct or retrograde, and with what period. But the uncertain tilt of the equator of Venus with respect to its orbital plane complicates the problem. Dr. Drake concluded that more precise measurements of radio radiation from Venus are needed, along with a better distribution around the orbit.

Jupiter has provided even more surprises than Venus, and three different kinds of radio emission have been recorded. The first is the predicted thermal radiation, corresponding to a Jovian temperature of 130° Kelvin.

At wave lengths longer than three meters, however, Jupiter is emitting continuously at least three billion watts of radio energy, whose increase with wave length strongly suggests a nonthermal origin. No change in intensity with time has been positively detected for this second kind of radiation. As told on page 501 of Sky and Telescope for July, 1959, Dr. Drake believes this radiation is from high-energy electrons trapped in Van Allen belts surrounding Jupiter, like those of the earth.

Jupiter also emits a highly variable radiation at about 15 meters wave length, characterized by bursts lasting only a few seconds or minutes, but sometimes extremely intense. This radiation, which arises from disturbances in the Jovian ionosphere, seemed less conspicuous in 1959 than in the previous seven years, suggesting that it may be controlled to some extent by solar activity.

Amateur Astronomers

NORTHEAST CONVENTION

New York City's Junior Astronomy Club will be host to the Northeast regional meeting of the Astronomical League on Saturday, April 30th. Sessions are to be held in room 707 of the main building of New York University, 100 Washington Square E., beginning at 10 a.m.

The convention banquet will be at the Hotel New Yorker at 7 p.m. A visit to the American Museum-Hayden Planetarium is tentatively scheduled for Sunday, May 1st. Registration and program information may be secured from Arthur E. Pearlmutter, 118-60 Metropolitan Ave., Kew Gardens 15, N. Y.

GREAT LAKES CONVENTION

The Great Lakes Region of the Astronomical League will meet in Detroit, Michigan, Saturday and Sunday, July 30-31. Headquarters will be the Henrose Hotel. Program chairman is E. C. Balch, 96 Farrand, Highland Park 3, Mich. Exhibit information may be secured from Edward Fifield, 19326 Montrose, Detroit 35, Mich.

NORTHWEST CONVENTION

July 1st to 3rd are the dates for the Northwest regional convention of the Astronomical League. The meeting place will be the University of Oregon, with the Amateur Astronomy League of Eugene as host. Further information may be had from Roger Fidler, 1530 High St., Eugene, Ore.

SOUTHEAST CONVENTION

The Southeast Region of the Astronomical League will hold its annual convention in St. Petersburg, Florida, April 23-24, with the Suwannee Hotel as headquarters.

Feature speakers are to be Dr. Ruroy Sibley, league president Chandler Holton, and Arthur Gay of St. Petersburg Junior College. The St. Petersburg Astronomy Club is arranging the meeting.

Program time may be secured from John A. Ebel, P. O. Box 2802, University Sta., Gainesville, Fla., while housing arrangements can be made with Mrs. Robert E. Angell, 233 5th Ave. N., St. Petersburg, Fla.

PLANETARIUM IN NEW ZEALAND

Although it has a seating capacity of only 84, the planetarium at the War Memorial Museum, Auckland, New Zealand, accommodated some 6,000 persons during the first month of its operation. Six daily performances were needed to handle the large crowds after the opening last October 22nd.

The planetarium was given to the museum by the Farmers Trading Co., a local department store, to mark its 50th anniversary. It consists of a Spitz projector with accessories, the projection chamber, and other furnishings. R. A. McIntosh is in charge.

BRISBANE, AUSTRALIA

In connection with the centenary celebration of the state of Queensland in Australia, a year-long series of programs was given by the 177 members of the Astronomical Society of Queensland during 1959. One of the highlights was a four-day visit in June by Dr. and Mrs. Bart J. Bok. During this time Dr. Bok, who is director of Mount Stromlo Observatory at Canberra, delivered three talks, one on the structure of the galaxy.

Founded in 1927, the present organization of amateurs succeeded the Brisbane Astronomical Society, which was started in 1896. The centenary-year programs are presented in a 63-page mimeographed *Proceedings*, edited by the group's president, A. A. Page, 44 McCaul St., Taringa East, Brisbane S.W. 6, Queensland, Australia.

LA HABRA, CALIFORNIA

The La Habra Astronomical Society is comprised of eight members. David Dotson, 11014 S. Newcomb Ave., Whittier, Calif., is secretary.

The members of the Amateur Astronomy Club of Caguas, Puerto Rico, in front of their recently completed observatory. During the International Geophysical Year, these juniors took part in the meteor observing program. They have received professional guidance from the well-known Warner and Swasey Observatory astronomer, Victor M. Blanco, who comes from Puerto Rico.

THIS MONTH'S PROGRAMS

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. April 1, Dr. Otto Struve, National Radio Astronomy Observatory, "Some Problems in Radio Astronomy."

Dayton, Ohio: Miami Valley Astronomical Society, 8 p.m., Museum of Natural History. April 8, Dr. K. E. Kissell, "Finding Your Way in the Celestial Sphere." Also April 22, motion picture, Sounds from the Stars.

New Orleans, La.: Pontchartrain Astronomy Society, 8 p.m., Tulane University Observatory. April 1, Dr. J. Adair Lyon, Tulane University, "The Sun."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. April 6, Dr. Gerard de Vaucouleurs, Harvard Observatory, "Wonderful Worlds Beyond the Galaxy."

New York, N. Y.: Junior Astronomy Club, 8 p.m., Waverly building, New York University. April 23, Willy Ley, "The Base on the Moon."

Philadelphia, Pa.: Rittenhouse Astronomical Society, 8 p.m., Franklin Institute. April 1, Dr. John Merrill, Franklin Institute, "World-wide Programs on Eclipsing Stars."

Pittsburgh, Pa.: Amateur Astronomers Association of Pittsburgh, 8:15 p.m., Buhl Planetarium. April 8, Dr. George Huff, "The 'Push' for Space Travelers."

KENOSHA, WISCONSIN

There are 25 adult and six junior members in the Kenosha Amateur Astronomers. The secretary is Robert Henkel, 7625 18th Ave., Kenosha, Wis.

TWO CLUBS IN INDUSTRY

At International Business Machines in Poughkeepsie, New York, 36 amateurs have formed an astronomical society, with Sarkis Kaolian, IBM South Rd., as president.

Nineteen workers at the Union Carbide plant in Charleston, West Virginia, have set up the Questeers Amateur Astronomical Society, and have joined the Middle East region of the Astronomical League. The president is W. F. Shelton, Box 468, Charleston 22, W. Va.

JUNIORS IN PUERTO RICO

The Amateur Astronomy Club of Caguas was mentioned in this department in the December, 1957, issue. At that time we were starting to build our observatory, which is now completed. It is not a Palomar, Lick, or Yerkes, yet serves its purpose very nicely.

At present we are engaged in astrophotography with a 6-inch electrically driven telescope. Some of our first films were of the planet Venus.

ANDRES NIEVES, JR.
139 Dr. Rufo St.
Caguas, Puerto Rico

TORONTO, CANADA

The telescope making section of the Royal Astronomical Society of Canada, Toronto Centre, held 19 meetings last year, with an average attendance of 25. Over two dozen 6-inch reflectors and two 4-inch refractors were built. Four 10-inch and two 12-inch mirrors are being worked on at present, and at least 60 members are grinding 6-inch ones.

We had a very successful season showing the skies to the public. During 10 star parties in local parks, we were often overwhelmed by crowds. Our members also participated in similar occasions at the Toronto exhibition.

Four spare telescopes that we loan to youth groups were kept busy all summer.

JESSE KETCHUM
Royal Astronomical Society of Canada
252 College St.
Toronto 2B, Canada

NEW EDITOR OF "REFLECTOR"

Miss Christine H. MacGill, 3776 S.W. 28th St., Miami 34, Fla., has been appointed editor of the *Reflector*, the publication of the Astronomical League. She succeeds Mrs. Jane Gann, of Columbus, Ohio.

TWO LOUISIANA GROUPS

Twenty-five juniors have organized the Shreveport Junior Astronomical Society. Miss Sara Worley, 550 Floyd Lane, Shreveport, La., is president.

At Bastrop, four amateurs have formed the Morehouse Astronomical Association. Further information may be had from Robert Hancock, 909 Pleasant Dr., Bastrop, La.

RICHLAND, WASHINGTON

The Tri-Cities Amateur Astronomers is made up of 13 members from Richland, Pasco, and Kennewick. Interested persons should communicate with Byron Brenden, 1206 Cedar, Richland, Wash. The society has joined the Northwest Region of the Astronomical League.

LUBBOCK, TEXAS

The South Plains Astronomy Club has 21 adult and nine junior members. Its president is Steve Ebner, Box 4402, Tech Sta., Lubbock, Tex.

JUNIORS IN NEW HAMPSHIRE, PENNSYLVANIA, AND WISCONSIN

Thirty-six juniors and six adults make up the Clearview Astronomical Society, which is headed by Ronald F. Trudeau, 1050 Hayward St., Manchester, N. H.

Stephen Karpchuk, Jr., 3304 Oakmont Ave., Philadelphia 36, Pa., is president of the 10-member Brahe Astronomical Society in that city.

Another 10 juniors have formed the Franklin Astronomical Society, which may be contacted by writing Kenneth Zbytniewski, 7215 S. 37 Pl., Franklin, Wis.

HERE AND THERE WITH AMATEURS

Most of these societies hold regular meetings once or twice monthly, at which interested persons are always welcome. Details of each society's program can be obtained from the official whose name and address are given here.

*Members receive *Sky and Telescope* as a privilege of membership.
‡Member organization of the Astronomical League.
‡Member organization of the Western Amateur Astronomers.
°Society has junior section.
‖Independent junior society.

ALABAMA

BIRMINGHAM
Birmingham Astronomy Club *†
G. Morgan, 1608 Barry Ave. (9). TR 9-8405

FLORENCE
Tri-Cities Astronomy Club *
R. May, 606 River Bluff Dr., Sheffield. EV 3-7845

HUNTSVILLE
Rocket City Astronomical Assn. *†
G. A. Ferrell, 621 Franklin St. JE 4-4809

ARIZONA

PHOENIX
Phoenix Observatory Assn. *‡
A. H. Hoff, Phoenix College. AM 6-4441

TUCSON
Tucson Astronomical and Astronautical Assn. *†‡‡
D. Strittmatter, 1840 E. Lee St. EA 5-9453

ARKANSAS

LITTLE ROCK
Arkansas Amateur Astronomy Club *†
C. P. Kulp, 1322 Donaghey Bldg.

CALIFORNIA

BAKERSFIELD
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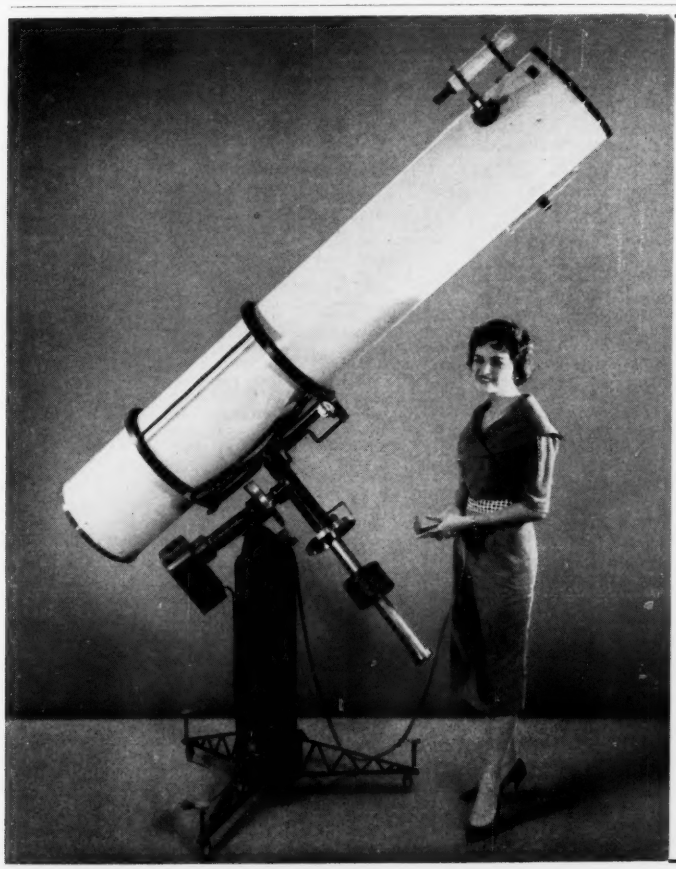

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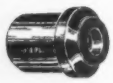

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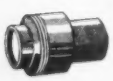

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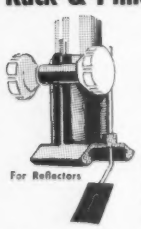

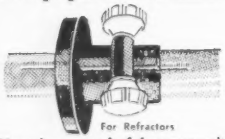

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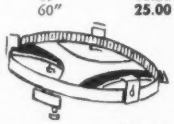

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Power	Field at 1,000 yards	Exit pupil diam.	Relative Brightness
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20	122	4.0	16
30	61	2.7	7
40	49	2.0	4
60	32	1.3	1

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54 mm. (2⅛")	508 mm. (20")	12.50
54 mm. (2⅛")	600 mm. (23½")	12.50
54 mm. (2⅛")	762 mm. (30")	12.50
54 mm. (2⅛")	1016 mm. (40")	12.50
54 mm. (2⅛")	1270 mm. (50")	12.50
78 mm. (3-1/16")	381 mm. (15")	21.00
80 mm. (3⅛")	495 mm. (19½")	28.00
81 mm. (3-3/16")	622 mm. (24½")	22.50
83 mm. (3¼")	660 mm. (26")	$28.00
83 mm. (3¼")	711 mm. (28")	28.00
83 mm. (3¼")	762 mm. (30")	28.00
83 mm. (3¼")	876 mm. (34½")	28.00
83 mm. (3¼")	1016 mm. (40")	30.00
102 mm. (4")	876 mm. (34½")	60.00
108 mm. (4¼")	914 mm. (36")	60.00
110 mm. (4⅜") *	1069 mm. (42-1/16")	60.00
110 mm. (4⅜")	1069 mm. (42-1/16")	67.00
128 mm. (5-1/16") *	628 mm. (24¾")	75.00
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OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

OBSERVING THE MOON — BURG AND LACUS MORTIS

IN the northwestern part of the moon, midway between the major craters Hercules and Eudoxus, lies the gray plain known as Lacus Mortis, the Lake of Death. Edmund Neison's classic book, *The Moon* (1876), describes it as "nearly circular in form, being 157 miles across from east to west, and 143 miles from north to south, with an area of 16,000 square miles, though from strong foreshortening elliptical in appearance. Its colour is on the whole less dark than the great grey Mares, but sufficiently so to render it clearly distinguishable in every illumination from the neighbouring surfaces."

H. P. Wilkins used the name Lacus Mortis for only the western part of this plain, but the International Astronomical Union's lunar atlas follows Neison's usage. The entire plain appears to me as a rhomboid, whose figure is best seen in its entirety under high solar illumination. Its surface is relatively smooth.

Situated near its center is the crater Bürg, 24 miles in diameter according to measurements by J. Young and D. W. G. Arthur. It is comparatively deep (about 6,300 feet), with many terraces on the interior walls which slope sharply to the floor. Although the floor itself has appeared to me to be quite convex, J. H. Mädler spoke of it as concave; it is largely occupied by a complex mountainous mass with two peaks. The outer slopes of Bürg are traversed by ravines and valleys descending to the level of the surrounding plain. Topping the walls are many sharp pinnacles, particularly on the east, which cast the deeply serrated shadow seen at sunrise, as drawn here.

That portion of Lacus Mortis lying to the east of Bürg is of great interest because of the large number of clefts that cross it, many visible in relatively small telescopes. The dominating feature is the very conspicuous line of fault entering Lacus Mortis from the south. Like the famous Straight Wall in Mare Nubium, the higher side of this fault is also on the west, and the difference in level between the two sides may amount to several hundred feet. There seems to be a low peak near each of its ends, as indicated by the somewhat irregular shadow cast at sunrise.

Alika Herring used a 12½-inch reflector at 236x for this drawing of the crater Bürg and the eastern part of Lacus Mortis, on June 12, 1959, at 4:10 Universal time. West is to the left and south above. The twin peaks inside the crater are lit by the western sun, and the irregular crest of the east wall casts a long jagged shadow on the plain.

The fault continues northward as a deep cleft which joins the long rill extending from the north, although the connection between the two is very difficult to see. Another conspicuous rill can be traced from near the northeast wall of Bürg to the southeast margin of Lacus Mortis. Unlike most clefts, it can be seen when the sun is high above it, appearing as a narrow bright line against the darker background of the plain.

This area contains a great amount of other fine detail: a number of small craterlets, some low domelike hills, and delicate rills. Much of this detail was not visible when the accompanying drawing was made, but experienced lunar observers know how greatly the detectability of minute features is affected by small variations in illumination and seeing conditions.

The floor of eastern Lacus Mortis is noticeably lower than the adjacent surface, as if it were formed by the subsidence of a large fault block in the lunar crust. It should therefore be considered to be a type of walled plain, despite its obviously noncircular shape.

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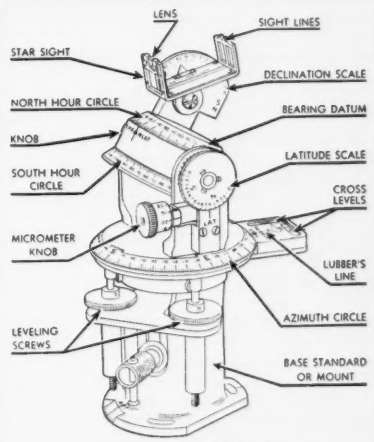

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A heavily spotted region of the sun was photographed by Howard C. Colton on January 23, 1959, using a 6-inch f/15 reflector and Kodak Autopositive sheet film. The exposure was made at the instrument's prime focus.

SOLAR PHOTOGRAPHY WITH AUTOPOSITIVE FILM

One ever-present problem for the amateur astronomer who photographs the sun is the great intensity of its light, making reduction of telescope aperture or very dense filters essential to avoid overexposure at normal camera shutter speeds. Howard C. Colton, of Eastman Kodak Co., now suggests the use of Kodak Autopositive P. B. sheet film, which is of very fine grain and very low sensitivity. At the prime focus of a 6-inch f/15 reflector, the solar image can be recorded on this emulsion with an exposure between 1/50 and 1/200 second, depending on the sun's altitude and the clearness of the air at the observer's station.

In order to provide a negative rather than the positive image usually obtained with this film, it is pre-exposed to sunlight through a yellow filter, after which the parts of the frame that receive no light during the camera exposure develop clear and transparent. Ordinary developers, such as D-19, are used, and the negative can be enlarged 15 or 20 times without showing grain. The accompanying picture and the one on page 14, November, 1959, indicate the results obtained by Mr. Colton.

A brief article containing the essential details of the process may be obtained free by writing to the Special Sensitized Products Sales Division of Eastman Kodak Co., Rochester 4, N. Y.

AURORAS IN FEBRUARY

A detailed report of the northern lights of February 15-16 has been written by David R. Kaiser, Eightyfour, Pennsylvania. Many form and color changes, of varying intensity, occurred through the night. This display was foreshadowed by a reddish glow in the northeast on the preceding evening.

Later, on February 27th at Des Moines, Iowa, Dale P. Cruikshank took the front-cover photograph, showing the aurora as a few isolated parallel vertical rays, which lasted only a short time.

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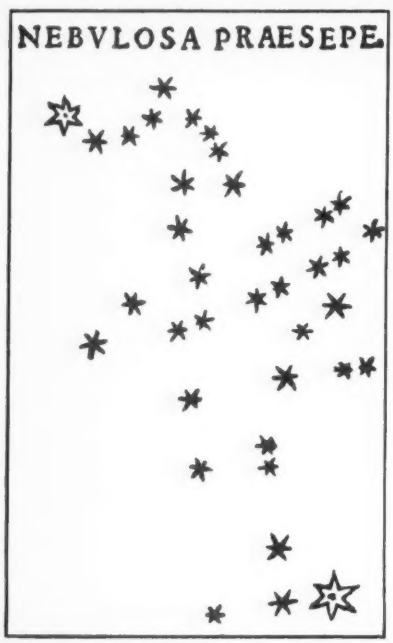
The famous naked-eye Beehive cluster (M44) in Cancer, photographed with the Palomar Observatory 48-inch Schmidt camera in blue light. The width of the field shown here is slightly over two degrees, and south is at the top, corresponding to the view in an inverting telescope. This open cluster is about 520 light-years distant.



Galileo's drawing of the Beehive.

DEEP-SKY WONDERS

THE region of the sky between Gemini and Leo is fairly vacant. Yet even though it is far above the galactic equator, here we find a striking open cluster — the Beehive in Cancer. Also known as the Praesepe, M44, and NGC 2632, this system has about 62 members brighter than magnitude 10 in an area of about two square degrees.

Individually, these stars are all under naked-eye visibility, though their combined visual magnitude is 3.7. Often on exceptional nights — always after midnight — I get the impression that I can see individual stars. However, telescopic views show that most of the brighter stars are in pairs or groups, and the whole effect is probably illusion. The photograph here certainly indicates that all of the brighter groups are too close for naked-eye separation at such low light intensity, in my opinion.

The name Beehive is apparently of fairly recent origin. To Hipparchus it was the Little Cloud; Aratos called it the Little Mist; and Bayer termed it Nubilum (cloudy sky). Astronomers of the 16th and 17th centuries called it the Nebula, and R. H. Allen (in *Star-Names*) says that it was the only universally recognized object that could not be resolved by ordinary vision. Its true nature was first discerned by Galileo, who wrote in his *Nuncius Sidereus* (1610): "The nebula called Praesepe, which is not one star only, but a mass of more than 40 small stars. I have noticed 30 stars, besides the Aselli."

This object is a fine test for clearness of the sky — the thinnest cirrus cloud will obscure it. When the cluster is boldly obvious, the night is a vintage one.

Telescopically, M44 is a little sparse, with no background of faint stars to set off the bright ones. However, in 50- or 65-mm. binoculars, or better yet a 120 x 20 Moonwatch apogee telescope, it is most impressive.

The Beehive is a wonderful object for the beginner at astrophotography; he can strap a box camera to an equatorially mounted telescope and hand guide for 15 or 20 minutes to obtain, with luck, a surprisingly fine picture.

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Listening to Meteors on Short Wave

SCATTERING of radio waves from the ionized tracks left by meteors has been studied extensively in recent years, and this phenomenon is now used constantly for long-distance radio communications. While elaborate equipment and careful preparation are needed for such work, amateur astronomers who are interested in meteors rather than in their applications to communications can make studies of both sporadic and shower meteors, even in cloudy weather.

Using ordinary short-wave radio receiving equipment at my home, with a 25-foot length of wire strung across the basement to serve as an antenna, I have made observations of many radio reflections from meteor trails. They have been heard for periods of several hours, appearing as whistles, loud bursts, and in other forms, at rates of 2,000 per hour or more at times.

The method depends on reception of the ground wave from some powerful short-wave transmitter simultaneously with the station's sky wave scattered from the meteor track. When the sky wave combines with a relatively weak ground wave, the increase in volume appears as a burst of noise or a whistle. However, the method does seem to require very special receiving conditions, the problem being to locate the receiver properly with respect to the transmitter. There is no way of telling just which observers will find the proper combination of circumstances at their respective locations.

At my home, only one short-wave broadcasting station among those heard in Berkeley, California, satisfies the conditions of high transmitted power, weak to moderate ground-wave reception, and favorable sky-wave angle. This is the Voice of America station KCBR in Delano, which is about 220 miles southeast of Berkeley.

My receiver was built from war-surplus items, and is probably quite inferior to most modern communications receivers. It is, however, rather selective (band-width about four or five kilocycles per second), so that background noise is reduced.

The meteor "echoes" have been best observed on frequencies in the 31-meter band, particularly after midnight, but they can also be picked up in the 51- and 19-meter bands and at other evening hours. Whistles are more numerous than intensity bursts; they occur in the lower part of the audio spectrum and vary in pitch in a number of ways — falling, rising, undulating, constant — from zero to about 1,000 cycles per second or higher.

Faint whistles are very numerous and often show no change in signal intensity as read on the signal-strength meter (which has automatic volume control). Loud whistles that descend in pitch to zero usually terminate in a burst of signal

Meteors passing through the atmosphere leave a trail of ionized particles that has the ability to reflect radio energy in the short-wave band, as well as higher frequencies. Such reflections can be detected as sudden bursts of increased signal strength, or as whistles, on receivers monitoring the transmitted signal at suitable locations. This bright meteor was photographed by Dennis Milon.

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intensity. Bursts may be very brief, but in some cases they endure for a minute or more with gradual fading. The reflections are easily detected even above the background of the program material, but are most distinct when only the carrier frequency is being broadcast, as during sign-on and sign-off periods. Probably the only effect of a meteor shower would be to increase the number of strong reflections received.

For individual cases, some experimentation may be needed to find a suitable location for the radio receiver. Where conditions are particularly good, an ordinary entertainment receiver capable of tuning a short-wave band may serve quite well. In any event, it is worth trying whatever equipment may be on hand at the start. If the receiver can be moved easily, it could be set up at several different locations a few miles apart until "echoes" are received. A portable all-wave receiver would be excellent for such tests.

Amateurs who hold "ham" radio licenses have the additional opportunity to broadcast a signal that can be beamed for reception by scatter, one of the most important techniques of meteor radio astronomy. This, of course, will broaden the scope of the investigations possible.

There are many studies that could be carried out with the technique described here. Variations in rate with time and wave length could be determined, and correlations with known meteor showers sought. New showers might be discovered, particularly if daylight hours prove favorable at some locations. If the receiver could be taken out under the stars during a widespread meteor shower, the results might be spectacular to the ear as well as to the eye.

ARTHUR F. SETTEDUCATI
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SUNSPOT NUMBERS

The following American sunspot numbers for January have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

January 1, 113; **2,** 112; **3,** 134; **4,** 157; **5,** 197; **6,** 191; **7,** 196; **8,** 182; **9,** 148; **10,** 158; **11,** 132; **12,** 127; **13,** 124; **14,** 121; **15,** 118; **16,** 121; **17,** 120; **18,** 94; **19,** 87; **20,** 94; **21,** 105; **22,** 135; **23,** 111; **24,** 153; **25,** 171; **26,** 164; **27,** 195; **28,** 184; **29,** 199; **30,** 194; **31,** 193. Mean for January, 146.1.

Below are provisional mean relative sunspot numbers for February by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations at Locarno and Arosa.

February 1, 173; **2,** 191; **3,** 184; **4,** 152; **5,** 142; **6,** 145; **7,** 123; **8,** 116; **9,** 143; **10,** 143; **11,** 115; **12,** 116; **13,** 97; **14,** 114; **15,** 94; **16,** 84; **17,** 73; **18,** 60; **19,** 50; **20,** 49; **21,** 46; **22,** 50; **23,** 56; **24,** 74; **25,** 80; **26,** 82; **27,** 89; **28,** 82; **29,** 78. Mean for February, 103.5.

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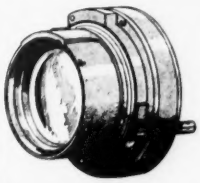

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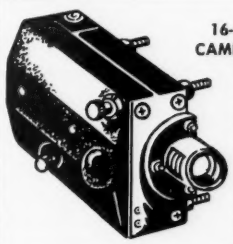

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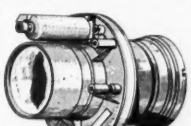

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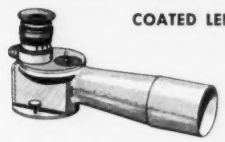

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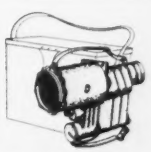

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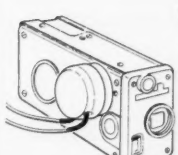

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BOOKS AND THE SKY

RADIO STUDIES OF THE UNIVERSE

R. D. Davies and **H. P. Palmer.** D. Van Nostrand Co., Inc., Princeton, N. J., 1959. 200 pages. $5.00.

BOTH R. D. Davies and H. P. Palmer are staff members at the Jodrell Bank Experimental Station of the University of Manchester, in England. Their book, therefore, is an authoritative account of radio astronomy as it appears to those actually working in the field.

The reader is first introduced to astronomy as a whole with a four-page historical survey and a brief but excellent summary of the major facts of optical astronomy, covering topics from the solar system to the universe, and from spectroscopy to stellar evolution.

With this as background, the authors proceed to radio astronomy itself, beginning with a description of the techniques employed. The principles of radio antennas and receivers, interferometers, and radar methods are all discussed, especially with regard to the advantages and shortcomings inherent in each. Many diagrams, pictures, and tables are included, which are most useful for those who wish to go into the subject deeply. The general reader will probably prefer to skim this chapter.

The remainder of the book is given to the results which had been obtained by the time of the writing, the unsolved problems, and the general directions in which research is moving.

Chapter IV is concerned with the major discrete radio sources. Copious illustration helps the reader appreciate the problems raised by the observation of strong sources in Cygnus, the Andromeda nebula, the galactic center, Cassiopeia, the Crab nebula, and the planet Jupiter. The authors place as much stress on the unexplained as on the definitely established facts. Where several possible explanations of the observations have been postulated, a brief summation of the pros and cons of each is listed.

Under the topic "The Radio Universe," the types and distributions of radio sources, both galactic and extragalactic, are treated, as well as what is known of their diameters and distances. There is a discussion of what, if any, light these facts have shed on cosmological ideas.

The radio mapping of our galaxy is the subject of the sixth chapter. Here, with many clear diagrams and descriptions, the authors show how a picture of the galaxy was obtained first from low-frequency intensity surveys, and later refined and clarified by means of the profiles of the 21-centimeter hydrogen line.

A section on the radio sun is followed by another that surveys the results of radar studies of the planets and meteors, and what has been learned about the earth's atmosphere as a by-product of radio and radar measurements. The final chapter looks into the future of radio astronomy and deals with the types of questions which may soon be answered, when more sensitive and more accurate instruments become available.

On the whole the book is accurate and concise. The illustrations are numerous and excellent, though not always well placed. The chapter on the Milky Way is particularly good. However, the reader who has no technical background will probably find the book difficult, despite the omission of mathematical treatments. The glossary is helpful, but many of the concepts might be more fully explained.

Along with *Radio Studies of the Universe,* I should like to recommend *The Exploration of Space by Radio,* by R. Hanbury Brown and A. C. B. Lovell (John Wiley and Sons, Inc., New York, 1958). While the latter is more technical, suitable as a handbook for the radio astronomer, it is so well written that large portions will be of great interest to the layman. The combination of the two books provides as good a coverage of the field as can be obtained at present.

PEARL R. LICHTENSTEIN
Rensselaer Polytechnic Institute

THE SKY OBSERVER'S GUIDE

Newton Mayall, Margaret Mayall, and **Jerome Wyckoff.** Golden Press, New York, 1959. 125 pages. $2.95.

THIS inexpensive handbook for amateur astronomers is a beautifully illustrated beginner's guide to observing the moon, sun, planets, stars, and other sky objects, whether with the naked eye, binoculars, telescope, or camera. It not only helps the reader to find these objects, but tells him things to do once they are located, things that may have some scientific value.

It does so with concise and clear explanations and illustrations, many of the latter in color. Every available inch is given to astronomical information. The attractive cover shows the equipment an amateur uses; the end-papers have a star chart of the entire heavens along with drawings of the mythical zodiacal constellation figures; the title page contains a picture of the Tycho-Clavius region on the moon; and the table of contents is decorated with the planet symbols. The index is very handy, since it is all kept on two facing pages.

About 1,500 stars down to the 5th magnitude are plotted in the eight charts at the end of the book. Five colors are used to show spectral classes. Variable stars, double stars, novae, galaxies, and nebulae, listed elsewhere in the book, are located. The maps also depict constellation boundaries and have connecting

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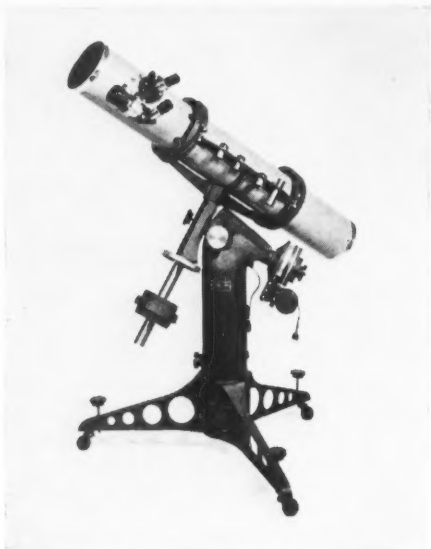

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lines between the stars to facilitate recognition.

Included in the text are chapters on using a telescope, drawing sky objects, tracking artificial satellites, using astronomical time, and so forth. Most of the chapters include tables of such information as total lunar eclipses from 1959 to 1964, planet locations from 1959 to 1965, the 25 brightest stars, prominent meteor showers, well-known variable stars, and some interesting double stars.

Well-executed paintings by John Polgreen depict certain sky objects as only visual observers often see them. For instance, on page 9 the realistic portrait of the Orion nebula is one of few I know of that shows the Trapezium and surrounding nebulosity as viewed in a small telescope. For those who prefer a photographic version of the nebula, there is one on page 95.

Although primarily an observing guide, the book concisely discusses many basic principles, such as resolving, magnifying, and light-gathering power of the telescope, star magnitudes, sky co-ordinates, and causes of eclipses.

It is gratifying to note that some of this book's excellent photographs were provided by amateur astronomers. The authors and the illustrator are all members of the American Association of Variable Star Observers.

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THE RAINBOW

Carl B. Boyer. Thomas Yoseloff, New York, 1959. 376 pages. $10.00.

SINCE prehistory, all who have watched the sky have been fascinated by the rainbow, their reactions being recorded in forms ranging from myth and poetry to mathematics. Many outstanding astronomers, including Kepler, Newton, and Airy, have been key figures in over 2,000 years of scientific effort to account for the properties of the rainbow.

Professor Boyer is a specialist in the history of science who has "taken advantage of the opportunity which the rainbow affords of bridging the gap between the sciences and the humanities." His book is not only the story of the development of ideas in optics, but an account of how they have influenced the fine arts and poetry.

As early as the 5th century B.C., the Greek philosopher Anaxagoras declared that the rainbow is the reflection of the sun from a cloud, and this notion of reflection as the basic cause persisted, in different forms, until a few hundred years ago. Aristotle elaborated the concept, drawing on strangely erroneous optical theory.

The successive steps by which the modern explanation developed are told in full detail by Dr. Boyer. Most books incorrectly state that the 13th-century Polish physicist Witelo or Vitello originated the idea that the refraction of light in raindrops causes the rainbow. He had been anticipated a generation earlier by Robert Grosseteste in England, who in turn may have encountered the idea in Arab writings.

At the beginning of the 17th century, Kepler applied long thought to the origin and form of the rainbow. He progressed from crude, immature speculations in a book of 1602 to a very nearly correct geometrical interpretation in his posthumously published notebooks. Kepler's contemporary, Marco Antonio de Dominis, who was Archbishop of Spaleto, made a notable advance by correctly suggesting that the primary bow is formed by two refractions and one reflection inside each raindrop, and the secondary bow by two refractions and two reflections.

The first satisfactory theories of the rainbow from geometrical optics were those of Descartes and Newton in the 17th century. The former quantitatively explained the 42-degree sharp inner radius of the bow by the total internal reflection of light within water drops; Newton was able to account for the sequence of colors.

Dr. Boyer traces the steps by which the wave theory of light, in the hands of Young, Airy, Clerk Maxwell, and others,

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was applied with increasing mathematical refinement to predict the detailed properties of rainbows. Thus, by the late 19th century, the distribution of light in bows caused by raindrops of different sizes could be calculated with great exactness. Many previously mystifying phenomena now took their places in an orderly scheme. For example, the whiteness of fogbows was found to be due to very small droplets, about 0.1 millimeter in diameter.

Scarcely any natural phenomenon seems further from practical use than the rainbow. Nevertheless, during World War II the National Advisory Committee on Aeronautics began an extensive study of rainbows. In aircraft icing, the size of water droplets in clouds is of great importance, and it was found that this information could be reliably obtained by measuring the viewing angle between the principal bow and the first supernumerary arc.

These few highlights give a very incomplete idea of the rich content of *The Rainbow*. Many books about the history of science contain very little science. It was complained of one large tome about a certain historical comet that its author left out all the astronomically useful information about the comet! No such reproach can be directed against Dr. Boyer. His well-illustrated book will interest those concerned with atmospheric physics as well as the historian of scientific ideas.

J. A.

THE PLANET VENUS

Patrick Moore. Macmillan Co., New York, 1959. 151 pages. $3.75.

FIRST published in late 1957, *The Planet Venus* now appears in a second edition, enlarged and so extensively rewritten as to constitute a new book. The change is enough to require a corresponding revision of the review on page 305 of SKY AND TELESCOPE for April, 1958.

The volume retains its general character as a well-informed descriptive account of the earth's nearest planetary neighbor, emphasizing historical rather than technical matters. Mr. Moore has, however, added much additional material, and a large number of minor flaws have been corrected or removed.

Noteworthy among the additions is a list, provided by M. B. B. Heath, of elongations and other phenomena of Venus from the year 1959 to 2000. This is valuable information for practical observers. But in the headings of each of the five pages of this table stands "Diameter, inches" instead of "Diameter, seconds of arc" — an error indicative of the generally inadequate proofreading.

The number of references to the literature concerning Venus has been increased to 384 from 155 in the first edition. Mr. Moore has thereby rendered a useful bibliographic service. But his listing of 85 attempts to determine the planet's rotation period, none of which have gained general acceptance, is a depressing exhibit of three centuries of fruitless effort.

So useful a book, the first in the English language devoted entirely to the subject, will presumably go through further editions, in which some remaining errors should be corrected. Thus, on page 89, credit for the Venus radar experiment should go to Robert Price, not Prince. On pages 118 and 119, the dimming of a star undergoing occultation by Venus is incorrectly attributed to absorption, instead of differential refraction. Surely the quip about F. P. von Gruithuisen on page 108 should be eliminated; his true scientific stature has been mistakenly belittled by Mr. Moore.

Whether for rainy-night reading by the amateur or for the observatory library, *The Planet Venus* is strongly recommended. Those who already own the first edition will find it worth while to obtain the new version also.

W. E. S. and J. A.

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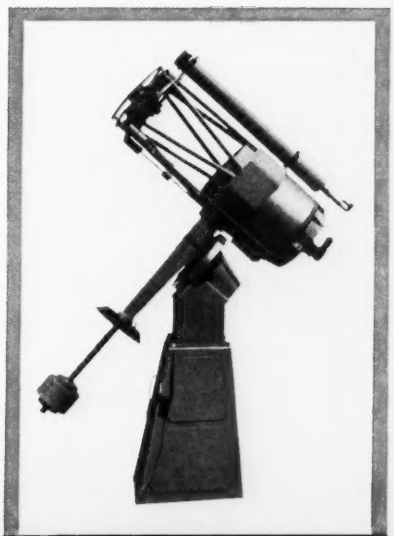

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SPACE FLIGHT I: ENVIRONMENT AND CELESTIAL MECHANICS, *Krafft A. Ehricke*, 1960, *Van Nostrand*. 513 pages. $14.50.

This volume is a detailed summary of solar system data relevant to interplanetary flight, and of the principles of celestial mechanics that are the foundation of space-flight theory. It is the first of three books contributed by the author to a new series entitled *Principles of Guided Missile Design*, edited by Capt. Grayson Merrill.

THE SKY IS OUR WINDOW, *Terry Maloney*, 1960, *Sterling*. 128 pages. $3.95.

Here is a simple, illustrated survey of astronomy for the layman who has a beginning interest in the heavens.

THE AMERICAN EPHEMERIS AND NAUTICAL ALMANAC FOR THE YEAR 1961, *Nautical Almanac Office*, U. S. Naval Observatory, 1959, *U. S. Government Printing Office*, Washington 25, D. C. 523 pages. $4.00.

This standard reference work for astronomers follows the new format begun in the volume for 1960. There are precise ephemerides for the sun, moon, planets, and the first four asteroids, and much other information of value to the serious observer. A widely useful feature is the day-by-day listing of astronomical phenomena.

MOVING ENVELOPES OF STARS, *V. V. Sobolev*, 1960, *Harvard University Press*. 106 pages. $4.75.

This is a translation by Sergei Gaposchkin of V. V. Sobolev's 1947 Russian treatise. The work is a mathematical treatment of radiative equilibrium in a moving medium, applied to the envelopes of emission-line stars and novae.

HANDBOOK FOR SPACE TRAVELERS, *Walter B. Hendrickson, Jr.*, 1959, *Bobbs-Merrill*. 256 pages. $3.95.

Written for young readers, this book is an explanation of rockets and the problems of space travel. The planets and their satellites are described in some detail.

FIGURES OF EQUILIBRIUM OF CELESTIAL BODIES, *Zdenek Kopal*, 1960, *University of Wisconsin Press*. 135 pages. $3.00.

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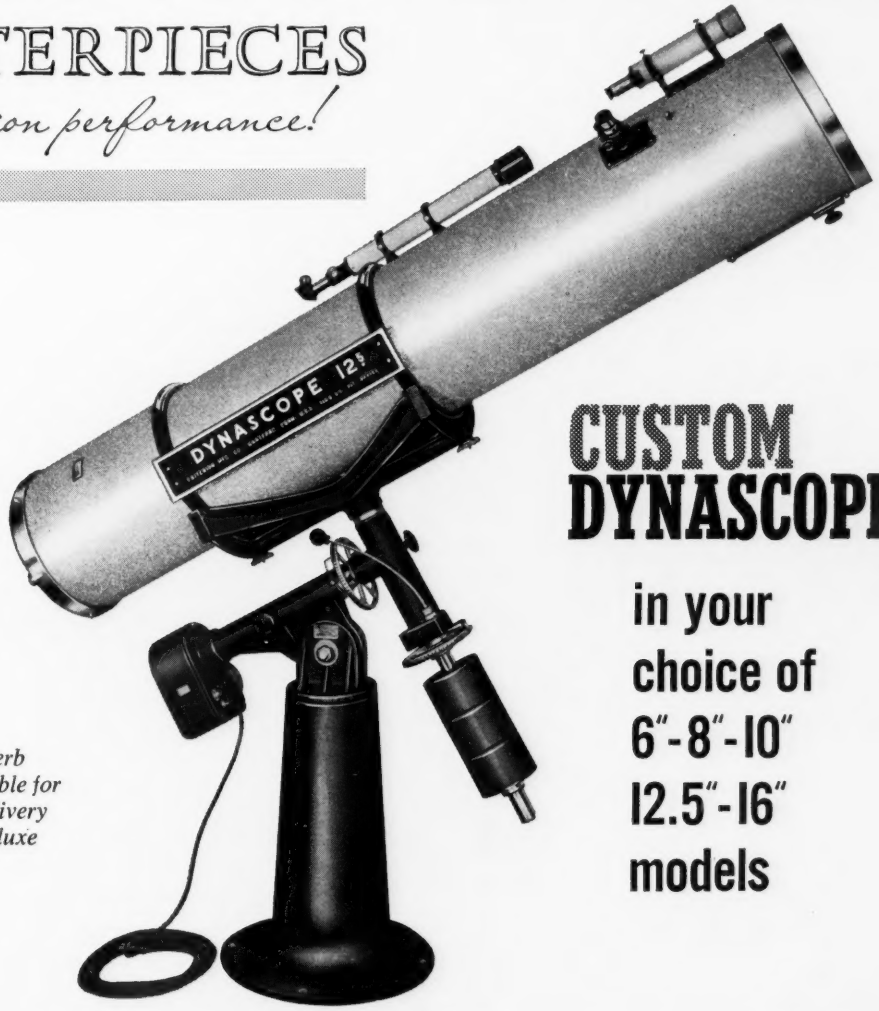

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STRANGE WORLD OF THE MOON, *V. A. Firsoff*, 1959, *Basic Books*. 226 pages. $6.00.

A British amateur astronomer presents his interpretation of observations of the moon, discussing the origin of its surface features, lunar colors, possible changes on the moon, and the existence of a lunar atmosphere. The mathematical details of his reasoning are collected in a 35-page appendix.

SPACE FLIGHT I: ENVIRONMENT AND CELESTIAL MECHANICS, *Krafft A. Ehricke*, 1960, *Van Nostrand*. 513 pages. $14.50.

This volume is a detailed summary of solar system data relevant to interplanetary flight, and of the principles of celestial mechanics that are the foundation of spaceflight theory. It is the first of three books contributed by the author to a new series entitled *Principles of Guided Missile Design*, edited by Capt. Grayson Merrill.

THE SKY IS OUR WINDOW, *Terry Maloney*, 1960, *Sterling*. 128 pages. $3.95.

Here is a simple, illustrated survey of astronomy for the layman who has a beginning interest in the heavens.

THE AMERICAN EPHEMERIS AND NAUTICAL ALMANAC FOR THE YEAR 1961, *Nautical Almanac Office*, U. S. Naval Observatory, 1959, *U. S. Government Printing Office*, Washington 25, D. C. 523 pages. $4.00.

This standard reference work for astronomers follows the new format begun in the volume for 1960. There are precise ephemerides for the sun, moon, planets, and the first four asteroids, and much other information of value to the serious observer. A widely useful feature is the day-by-day listing of astronomical phenomena.

MOVING ENVELOPES OF STARS, *V. V. Sobolev*, 1960, *Harvard University Press*. 106 pages. $4.75.

This is a translation by Sergei Gaposchkin of V. V. Sobolev's 1947 Russian treatise. The work is a mathematical treatment of radiative equilibrium in a moving medium, applied to the envelopes of emission-line stars and novae.

HANDBOOK FOR SPACE TRAVELERS, *Walter B. Hendrickson, Jr.*, 1959, *Bobbs-Merrill*. 256 pages. $3.95.

Written for young readers, this book is an explanation of rockets and the problems of space travel. The planets and their satellites are described in some detail.

FIGURES OF EQUILIBRIUM OF CELESTIAL BODIES, *Zdenek Kopal*, 1960, *University of Wisconsin Press*. 135 pages. $3.00.

This mathematical treatise deals with the hydrostatic theory of self-gravitating celestial bodies, and emphasizes problems of motions of artificial satellites.

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A Silo-Domed Observatory for a 12½-inch Telescope

EARNING my livelihood in the construction and building supplies business assisted me considerably in building my observatory, which houses a 12½-inch Newtonian reflector. It is the result of an interest in astronomy that started 10 years ago when I spent an autumn evening observing through another amateur's 6-inch telescope. My host on that occasion, Perle Guess, talked me into grinding my first mirror, and several years later I built the larger instrument, mounting it on a temporary post in my back yard.

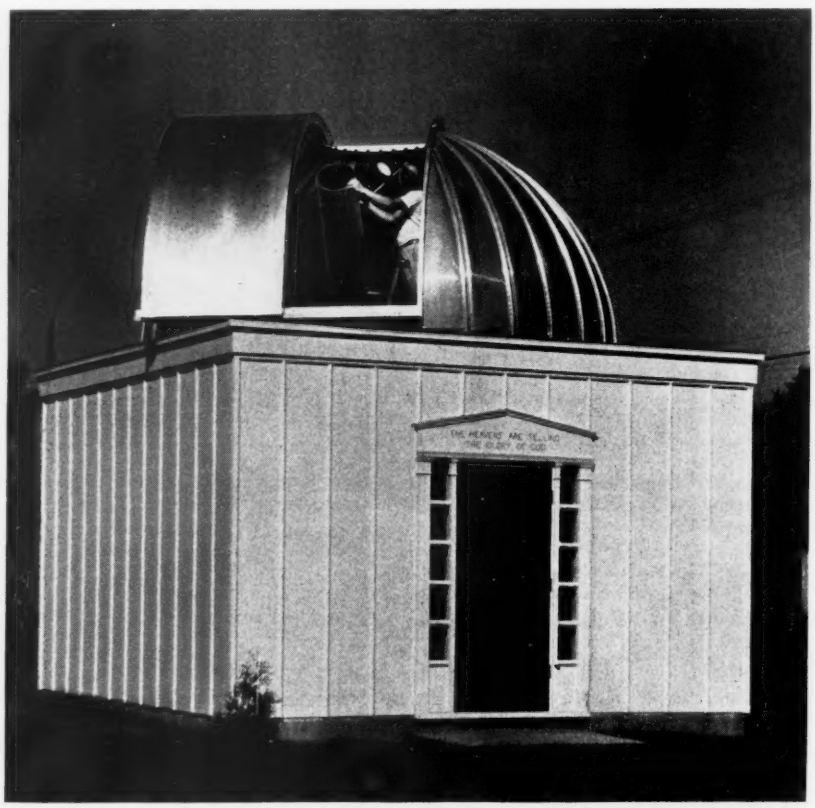
In 1956, I received a permit to build the observatory on a lot behind my house and began by pouring a foundation 16′ square. The building frame was covered with Masonite and Homosote siding, a batten strip being placed on each stud. The base ring of the revolving dome was made of curved laminated wood, providing a strong, inexpensive unit that is light in weight.

Such a laminated ring may be made with a minimum of tools. Use a beam compass or some other device to scribe an arc of the required radius (7′ for my dome) on a wooden floor or platform. Drive large nails every 6″ along this curve to make a forming jig. The strips to be laminated should be as long as the rafter desired, each strip having a ¼″-by-1⅝″ cross section. About 14 or 15 strips are needed for a rafter the approximate size of a finished 2-by-4.

Elmer's, Wood Lock, Weldwood, or a similar glue should be applied to the flat surfaces of each strip. Do not try to start with more than three strips for the first bend. Clamp these around the curve of nails and glue on more strips. Small nails can be used to tack successive laminations. Be sure the joints are making good contact, but do not clamp the strips too tightly together, because a very tight, glue-starved joint might eventually let go under stress or from aging. The finished rafter should be belt-sanded to produce a professional-looking job. My entire dome ring was laminated by this method, as were the slit-opening rafters.

The dome is a 14′ De Muth silo top, reworked to provide a wide slit with an opening past the zenith. Although weighing nearly 300 pounds, it turns easily on six hand-truck hard-rubber wheels. The aluminum-covered shutter rolls on 4″ sheaves.

The pier for the mounting was poured into a standard 18″ cardboard tube available at most concrete suppliers. When the tube is stripped off the hardened con-



The first floor of Nathan Roth's observatory now contains only the stairs to the observing platform, but it will be used for charts. Photo by Ray Barth.

The author and his 12½-inch Newtonian telescope, on the temporary mounting used in his back yard before the large observatory was built. The sunscreen support (pictured below) had not yet been added to the tube.

crete, the job is nicely finished. It is recommended that in cold climates, such as ours in Wisconsin, the bottom of the pier be 3′ or 4′ below ground level — mine is 5′ deep to be on the safe side.

For the mounting itself, I used the standard German equatorial design, with a polar axle of 2¼″ steel in link-belt heavy-duty ball bearings. The mount was constructed by a machinist friend, to whom I supplied a complete wooden mockup so he would understand the principle of operation involved.

An 18-point flotation system supports the mirror and preserves its figure in any position of the telescope. A ball-and-socket joint from an old camera tripod is placed between the spider and diagonal, aiding materially in obtaining good alignment with a minimum of effort.

As an active merit-badge councilor for the Boy Scouts of America, I have used the observatory to create interest in the stars among local boy scouts and school children, to whom the telescope is regularly available. To hear a youngster's reaction at his first observation of the moon is reward enough for any telescope maker.

NATHAN R. ROTH
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At the eyepiece end of the telescope, a long rod is firmly mounted to a plate on the main tube. This rod holds a piece of white-painted aluminum siding that serves as a screen for eyepiece projection of the sun's image. A single-lens reflex Exa camera can also be attached to the rod for taking pictures of the moon. Photograph by Ray Barth.

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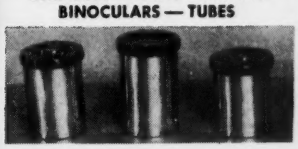

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Concerning Spherical-Mirror Telescopes

"SINCE most amateur telescope makers find it very much easier to make a good concave spherical surface than a good surface of any other shape, and since a suitably proportioned telescope can give excellent results with a spherical primary mirror, there seems very little point in an amateur's going to the trouble of parabolizing, especially for his first telescope.

"It is true that the focal length must be increased somewhat beyond what is normal at present; and for this reason a spherical-mirror telescope may be considered inconvenient when the aperture exceeds seven inches. However, for the very commonly used 6-inch aperture telescope an increase in the focal length from the usual 48 inches to about 60 inches is sufficient to ensure good performance without parabolizing, and few amateurs would object to the modest increase in tube length."

These are the concluding words of "Simple Telescopes with Spherical Mirrors," an article by N. J. Rumsey, of the Dominion Physical Laboratory in New Zealand. It was published last September in *Southern Stars*, the journal of the Royal Astronomical Society of New Zealand.

As is well known, the primary mirror of a reflecting telescope of conventional focal ratio, say f/4 to f/8, must be figured to a paraboloid if the definition of the image in the center of the field is to be as perfect as diffraction effects and seeing conditions will permit. But many novices at telescope making spoil a good spherical mirror in attempting to parabolize it, and there are cases where even professional astronomers can use long-focus optics for which parabolizing the mirror is needless effort.

Mr. Rumsey points out that the visual performance of a terrestrial telescope is generally considered to be good if the spherical aberration is corrected to within the Rayleigh limit; that is, each wave front converging toward an image point departs from the ideal shape by not more than one-quarter of the wave length of light (usually green, to which the eye is most sensitive).

However, many experienced observers agree that this amount of spherical aberration impairs the definition too much for astronomical purposes. But the definition improves inversely in proportion to the square of the amount of aberration, and the New Zealand physicist suggests that the aberration be allowed to reach the Rayleigh limit in the violet, where the wave length is very short. In such a case, the aberration would be about three-fourths of the limit in the green and little more than one half in red, giving performance more than adequate for most purposes. Further, he says, "The performance should be indistinguishable from that of a perfect instrument if the aberration is reduced to half the Rayleigh limit in deep violet light."

He gives the following formula for calculating the proper focal ratio, N, for various apertures of spherical mirrors:

$$N = 6.25\ (a/2L)^{\frac{1}{3}},$$

where a is the aperture in inches and L is the Rayleigh limit expressed as a fraction of the wave length of violet light (4064 angstroms).

For values of L equal to 1 and $\frac{1}{2}$, respectively, the following table is easily calculated from the formula:

Aperture	L = 1		L = ½	
(inches)	*N*	*F. L.*	*N*	*F. L.*
2	6.3	12.5	7.9	15.8
3	7.2	21.5	9.0	27.0
4	7.9	31.5	9.9	39.7
5	8.5	42.5	10.7	53.5
6	9.0	54.0	11.3	68.0
7	9.5	66.5	12.0	84.0
8	10.0	80.0	12.5	100.0
9	10.3	93.0	13.0	117.0
10	10.7	107.0	13.5	135.0
12	11.3	136.0	14.3	172.0
12½	11.4	142.6	14.5	181.4
14	12.0	168.0	15.0	211.0
16	12.5	200.0	15.8	252.0

Comparison of the two principal columns of the table shows that for any particular aperture an increase in focal length of only about 25 per cent will halve the spherical aberration. These columns represent the practical lower and upper limits within which the focal length of a spherical primary mirror should lie. There is little detectable improvement in performance for longer focal lengths, and any shortening of the values given for the full Rayleigh limit will cause a rapid deterioration in performance.

Our New Zealand author gives some important precautions to be observed with spherical reflectors. First, even with the increased focal lengths it is not advisable to use Huygens eyepieces, for they have the worst undercorrection of all ocular designs. Spherical aberration in any spherical mirror-Huygens eyepiece combination reaches the full Rayleigh limit

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at f/12, and the most satisfactory performance requires an f/15 telescope or longer. But Ramsden, orthoscopic, Erfle, Kellner, and symmetrical eyepieces will work well with long-focus spherical mirrors.

The diffraction effects of an oversized diagonal must be avoided. For a paraboloid, the diagonal's minor axis should not be more than 25 or 30 per cent of the primary mirror's diameter. When the primary is spherical, the effects of spherical aberration are added to the diffraction by the diagonal, and the secondary obstruction should be limited to 20 or 25 per cent. Incidentally, a spherical primary cannot be used off-axis to avoid the need for a secondary, unless the focal length is increased to match that of a mirror with at least twice the primary's diameter.

Spherical mirrors, over a limited field, make satisfactory photographic telescopes. If the spherical aberration is well enough corrected for visual use, it is certainly good enough for photographic use. Over a field of half a degree or less, any of the mirrors within the limits of the table above will equal the photographic performance of paraboloidal telescopes with f/8 focal ratios.

The 25-per-cent increase in focal length between the columns in the table includes all practical values useful to the amateur. If a 6-inch telescope of 68″ focal length seems unwieldy to mount, reduce it to 60″, which is only 12″ more than the conventional length of a paraboloidal reflector. Actually, the increased magnification is well worth having for observations of the moon, planets, double stars, and many clusters. For example, whereas a ¾-inch eyepiece gives 64x with a 48-inch focus, 60x can be obtained with a 1-inch eyepiece and a 60″ focal length. This is more advantageous at higher powers.

Mr. Rumsey suggests using spherical mirrors to make a 4-inch Newtonian finder, focal length 31½″, with a 1½-inch eyepiece giving a power of 21x. With a five-millimeter exit pupil, and a real field of nearly two degrees, this is a very convenient finder for a large reflector. He suggests similarly a 4-inch Cassegrainian guide telescope, f/50, with an effective focal length of 198″. Finally, for a 7-inch Cassegrainian, he proposes an f/12 primary mirror to give an effective focal length of 420″. The eyepiece's real field is about eight minutes of arc.

It should be stressed that although spherical mirrors can be used to make good telescopes, they must be tested for surface smoothness and figure by the standard Foucault or Ronchi methods. Without testing, it is impossible to hold such surfaces within tolerances, no matter how carefully the polishing is done. Testing during polishing is essential to keep the mirror smooth enough and spherical enough to hold the image within the value of the Rayleigh limit adopted.

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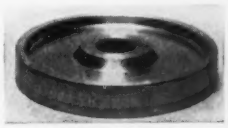

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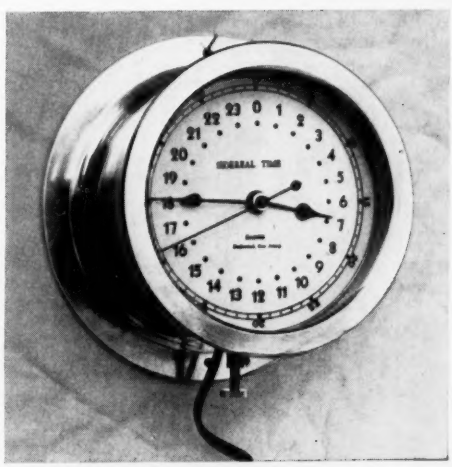

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"It is true that the focal length must be increased somewhat beyond what is normal at present; and for this reason a spherical-mirror telescope may be considered inconvenient when the aperture exceeds seven inches. However, for the very commonly used 6-inch aperture telescope an increase in the focal length from the usual 48 inches to about 60 inches is sufficient to ensure good performance without parabolizing, and few amateurs would object to the modest increase in tube length."

These are the concluding words of "Simple Telescopes with Spherical Mirrors," an article by N. J. Rumsey, of the Dominion Physical Laboratory in New Zealand. It was published last September in *Southern Stars*, the journal of the Royal Astronomical Society of New Zealand.

As is well known, the primary mirror of a reflecting telescope of conventional focal ratio, say f/4 to f/8, must be figured to a paraboloid if the definition of the image in the center of the field is to be as perfect as diffraction effects and seeing conditions will permit. But many novices at telescope making spoil a good spherical mirror in attempting to parabolize it, and there are cases where even professional astronomers can use long-focus optics for which parabolizing the mirror is needless effort.

Mr. Rumsey points out that the visual performance of a terrestrial telescope is generally considered to be good if the spherical aberration is corrected to within the Rayleigh limit; that is, each wave front converging toward an image point departs from the ideal shape by not more than one-quarter of the wave length of light (usually green, to which the eye is most sensitive).

However, many experienced observers agree that this amount of spherical aberration impairs the definition too much for astronomical purposes. But the definition improves inversely in proportion to the square of the amount of aberration, and the New Zealand physicist suggests that the aberration be allowed to reach the Rayleigh limit in the violet, where the wave length is very short. In such a case, the aberration would be about three-fourths of the limit in the green and little more than one half in red, giving performance more than adequate for most purposes. Further, he says, "The performance should be indistinguishable from that of a perfect instrument if the aberration is reduced to half the Rayleigh limit in deep violet light."

He gives the following formula for calculating the proper focal ratio, N, for various apertures of spherical mirrors:

$$N = 6.25\ (a/2L)^{\frac{1}{3}},$$

where a is the aperture in inches and L is the Rayleigh limit expressed as a fraction of the wave length of violet light (4064 angstroms).

For values of L equal to 1 and ½, respectively, the following table is easily calculated from the formula:

Aperture	L = 1		L = ½	
(inches)	*N*	*F. L.*	*N*	*F. L.*
2	6.3	12.5	7.9	15.8
3	7.2	21.5	9.0	27.0
4	7.9	31.5	9.9	39.7
5	8.5	42.5	10.7	53.5
6	9.0	54.0	11.3	68.0
7	9.5	66.5	12.0	84.0
8	10.0	80.0	12.5	100.0
9	10.3	93.0	13.0	117.0
10	10.7	107.0	13.5	135.0
12	11.3	136.0	14.3	172.0
12½	11.4	142.6	14.5	181.4
14	12.0	168.0	15.0	211.0
16	12.5	200.0	15.8	252.0

Comparison of the two principal columns of the table shows that for any particular aperture an increase in focal length of only about 25 per cent will halve the spherical aberration. These columns represent the practical lower and upper limits within which the focal length of a spherical primary mirror should lie. There is little detectable improvement in performance for longer focal lengths, and any shortening of the values given for the full Rayleigh limit will cause a rapid deterioration in performance.

Our New Zealand author gives some important precautions to be observed with spherical reflectors. First, even with the increased focal lengths it is not advisable to use Huygens eyepieces, for they have the worst undercorrection of all ocular designs. Spherical aberration in any spherical mirror-Huygens eyepiece combination reaches the full Rayleigh limit

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at f/12, and the most satisfactory performance requires an f/15 telescope or longer. But Ramsden, orthoscopic, Erfle, Kellner, and symmetrical eyepieces will work well with long-focus spherical mirrors.

The diffraction effects of an oversized diagonal must be avoided. For a paraboloid, the diagonal's minor axis should not be more than 25 or 30 per cent of the primary mirror's diameter. When the primary is spherical, the effects of spherical aberration are added to the diffraction by the diagonal, and the secondary obstruction should be limited to 20 or 25 per cent. Incidentally, a spherical primary cannot be used off-axis to avoid the need for a secondary, unless the focal length is increased to match that of a mirror with at least twice the primary's diameter.

Spherical mirrors, over a limited field, make satisfactory photographic telescopes. If the spherical aberration is well enough corrected for visual use, it is certainly good enough for photographic use. Over a field of half a degree or less, any of the mirrors within the limits of the table above will equal the photographic performance of paraboloidal telescopes with f/8 focal ratios.

The 25-per-cent increase in focal length between the columns in the table includes all practical values useful to the amateur. If a 6-inch telescope of 68″ focal length seems unwieldy to mount, reduce it to 60″, which is only 12″ more than the conventional length of a paraboloidal reflector. Actually, the increased magnification is well worth having for observations of the moon, planets, double stars, and many clusters. For example, whereas a ¾-inch eyepiece gives 64x with a 48-inch focus, 60x can be obtained with a 1-inch eyepiece and a 60″ focal length. This is more advantageous at higher powers.

Mr. Rumsey suggests using spherical mirrors to make a 4-inch Newtonian finder, focal length 31½″, with a 1½-inch eyepiece giving a power of 21x. With a five-millimeter exit pupil, and a real field of nearly two degrees, this is a very convenient finder for a large reflector. He suggests similarly a 4-inch Cassegrainian guide telescope, f/50, with an effective focal length of 198″. Finally, for a 7-inch Cassegrainian, he proposes an f/12 primary mirror to give an effective focal length of 420″. The eyepiece's real field is about eight minutes of arc.

It should be stressed that although spherical mirrors can be used to make good telescopes, they must be tested for surface smoothness and figure by the standard Foucault or Ronchi methods. Without testing, it is impossible to hold such surfaces within tolerances, no matter how carefully the polishing is done. Testing during polishing is essential to keep the mirror smooth enough and spherical enough to hold the image within the value of the Rayleigh limit adopted.

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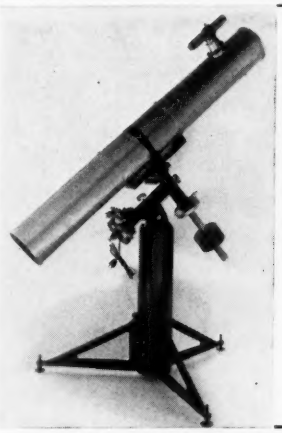

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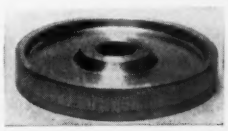

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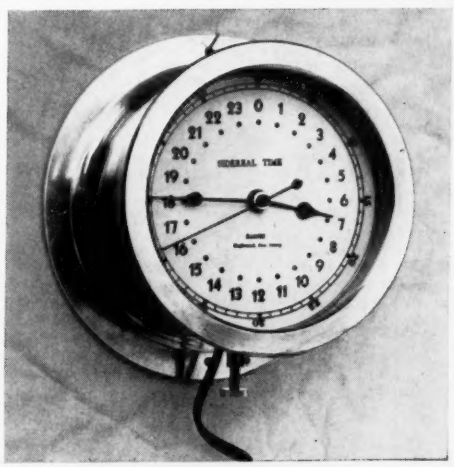

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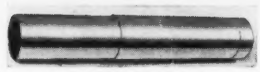

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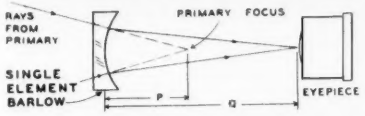

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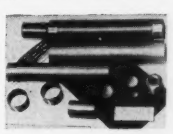

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CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

Occultations of the Hyades and of Aldebaran

On the early evening of Thursday, March 31st, the moon will pass in front of the Hyades, as seen from the western part of the United States and Canada. In eastern North America, the moon will have set before it reaches the star cluster. The most favored observers are those in British Columbia, Washington, and Oregon.

The moon's phase is five days after new, so the Hyades stars will disappear at the dark edge of its disk. No reappearances of bright members of the cluster are observable from North America. For each of five stations, the following list gives the station location, kind of standard time used, star number in the *Zodiacal Catalogue*, star magnitude, standard time of disappearance, and position angle (counted eastward around the moon's limb from the north point):

H, Denver, Colo., MST. 659, 6.4, 8:12, 148°.

J, Edmonton, Alta., MST. 659, 6.4, 7:33, 104°; 669, 4.0, 9:06, 110°; 671, 3.6, 9:17, 136°; 672, 6.6, 9:20, 64°.

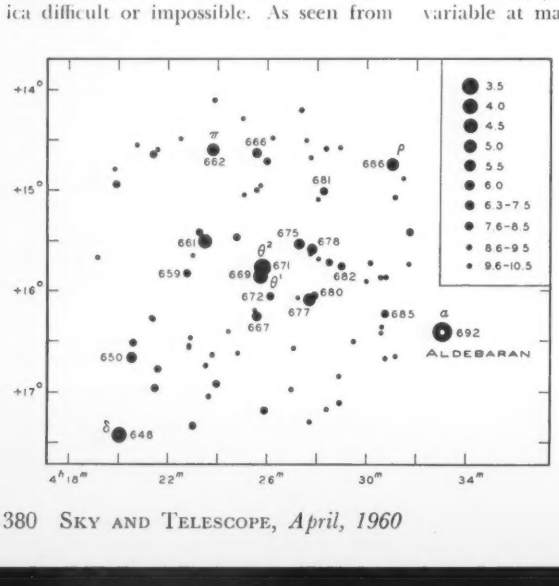
K, California, PST. 667, 5.3, 8:26, 68°; 672, 6.6, 8:44, 117°.

L, Oregon, PST. 659, 6.4, 7:03, 154°; 667, 5.3, 8:24, 47°; 672, 6.6, 8:33, 98°; 669, 4.0, 8:40, 160°.

M, Vancouver, B. C., PST. 659, 6.4, 6:36, 122°; 669, 4.0, 8:16, 129°; 672, 6.6, 8:22, 81°; 667, 5.3, 8:27, 17°; 677, 4.8, 9:09, 77°; 680, 6.7, 9:15, 88°.

More detailed predictions of these events, together with data for obtaining the times at local stations, were furnished in Sky and Telescope for last December, in the Occultation Supplement beginning on page 99.

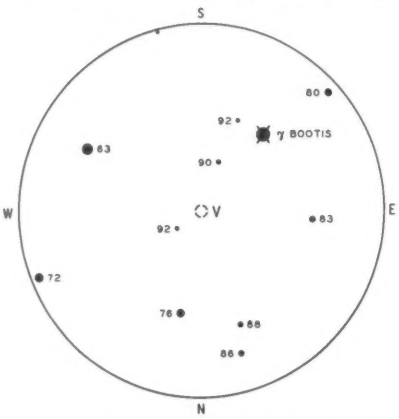
A daylight occultation of Aldebaran will take place on the morning of April 28th, but under circumstances that may make useful observations in North America difficult or impossible. As seen from central Massachusetts, the star disappears at 9:03 a.m. and reappears at 10:07 a.m. EST, from behind a 2.8-day-old crescent moon. However, the event occurs in the eastern sky below the sun. At places farther west, the occultation takes place with the moon lower in the east, under even more unfavorable conditions. Detailed predictions are given in the Occultation Supplement mentioned above.



The moon will occult stars in the Hyades cluster on March 31st and several other dates during the year, as indicated by the Occultation Supplement in the December, 1959, issue. This chart, adapted from the atlas of O. Kohl and G. Felsmann, shows many stars labeled with their numbers in the "Zodiacal Catalogue." South is at the top, matching the view in an inverting telescope.

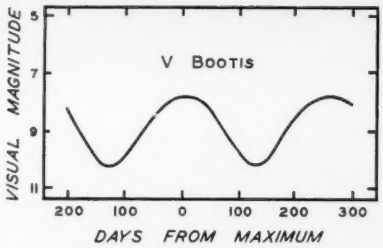
V BOOTIS

One of the easiest of long-period variables to identify is V Bootis, as it lies in the same finder field as 3rd-magnitude Gamma Bootis. The variable is 2.3 minutes of right ascension west and 33′ north of this naked-eye skymark. The accompanying chart will facilitate finding V when it is near greatest brightness in late April and early May.



This finder chart for V Bootis was adapted from the AAVSO "b" chart of the star. Its position is marked by the broken circle in the center. Magnitudes of comparison stars are given without decimal places, to avoid confusion with star symbols.

In recent years, the magnitude of this variable at maximum has been recorded as between 7.0 and 8.0, with the interval between consecutive maxima ranging from 243 to 270 days. The minima are quite varied in depth, some being as bright as magnitude 9.4 and others as faint as 11.3. The average period is 258.22 days, according to the current edition of the Moscow *General Catalogue of Variable Stars*.



The mean light curve of V Bootis, plotted by Leon Campbell from observations by members of the American Association of Variable Star Observers. Individual cycles may differ widely from this average behavior. From "Studies of Long Period Variables."

The Swedish astronomer N. C. Dunér discovered the variability of V Bootis on May 21, 1884, during the course of zone observations of stars with the meridian circle of Lund Observatory. Noting this star as fainter than magnitude 9.5 that night, he remembered that he had recorded it as 7.0 on April 29th and May 7th. He described the star as of an orange color, exhibiting in a visual spectroscope broad absorption bands in the blue-green and blue. This is in good accord with the modern classification of the spectrum as type *M*6e. In recent years, V Bootis has been intensively watched by members of American, British, and Scandinavian societies of variable star observers. The 1950 co-ordinates of this object are $14^h\ 27^m.5$, $+39°\ 05'$.

VARIABLE STAR MAXIMA

April 4, R Geminorum, 070122a, 7.1; 6, RS Scorpii, 164844, 7.0; 15, R Carinae, 092962, 4.6; 15, V Canum Venaticorum, 131546, 6.8; 24, V Ophiuchi, 162112, 7.5; 27, R Corvi, 121418, 7.5.

May 4, T Herculis, 180531, 8.0; 5, V Bootis, 142539, 7.9; 7, S Coronae Borealis, 151731, 7.3; 8, S Pictoris, 050848, 8.1.

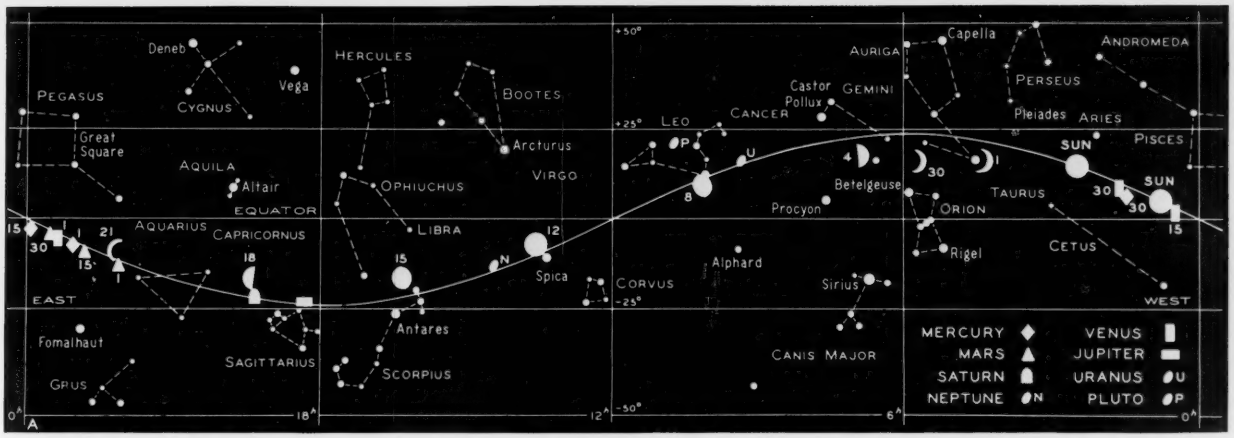
These predictions of variable star maxima are by the AAVSO. Only stars are included brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

MINIMA OF ALGOL

April 3, 13:27; 6, 10:16; 9, 7:06; 12, 3:55; 15, 0:44; 17, 21:33; 20, 18:22; 23, 15:11; 26, 12:00; 29, 8:49.

May 2, 5:38; 5, 2:27; 7, 23:16.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of the star's least brightness.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0h Universal time on the respective dates.

Mercury reaches greatest western elongation on April 7th, 28° from the sun, but it rises less than an hour before sunup on that date. The planet is low in the southeastern dawn sky, difficult to observe.

Venus is in the morning sky, but too near the sun to be observed this month.

Mars rises about 1½ hours before the sun at midmonth, and may be glimpsed low in the southeast, though still hard to locate. It is now in the constellation Aquarius, shining at magnitude +1.3.

Jupiter is in Sagittarius, rising about midnight, local time, in the middle of the month. Its magnitude then is −1.9, and the planet dominates the eastern sky in the early morning hours. Jupiter is stationary in right ascension on April 20th, beginning retrograde (westward) motion among the stars. In a telescope the somewhat flattened disk of the planet — 40″.8 in equatorial diameter — can be seen. The moon will pass 5° north of Jupiter on the 16th.

Saturn comes to western quadrature on April 8th, and rises about 1½ hours after midnight, local time. It can be seen low in the southeastern sky before dawn, as a bright object of magnitude +0.8. Saturn will be stationary in right ascension on the 27th, when it begins to retrograde among the stars. On the evening of the 17th the moon will pass 4° north of this planet.

According to the 1960 *Handbook* of the British Astronomical Association, Saturn and its rings will occult the 9.0-magnitude star BD −21° 5359 at the end of the month. Observing this event will be quite difficult, due to the great difference in brightness between planet and star.

Accurate predictions of times are impossible, because Saturn will be near its stationary point and moving only 1″ per hour. Tentative times indicate that the star will disappear at the outer edge of the rings at about 4h UT on April 30th in position angle 258°, and disappear at the planet's limb at 15h on the same date at 261°. Reappearance from behind the ball will occur on May 1st at 11h, 71°, from behind the rings at 18h, 75°. Observers with large telescopes may be able to use this event to locate divisions in the ring system.

Uranus is in western Leo, and crosses the meridian about an hour after sunset on the 15th. The field chart published on page 191 of the January issue will aid in locating this 6th-magnitude planet. Uranus is stationary in right ascension on the 24th, resuming direct (eastward) motion in the sky.

Neptune comes to opposition with the sun on April 28th, when it will be 2.7 billion miles from the earth. This 8th-magnitude object is in western Libra, as shown by the chart on page 191 of January. Its rising time toward the end of the month is at sunset, and it is above the horizon the whole night.

W. H. G.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.

MOON PHASES AND DISTANCE

First quarter	April	4, 7:05
Full moon	April	11, 20:28
Last quarter	April	18, 12:57
New moon	April	25, 21:45
First quarter	May	4, 1:01

	Distance	Diameter
April		
Apogee 2, 22h	251,400 mi.	29′ 32″
Perigee 14, 19h	227,000 mi.	32′ 42″
Apogee 30, 16h	251,900 mi.	29′ 29″
May		
Perigee 12, 18h	224,000 mi.	33′ 09″

APRIL METEORS

The Lyrid meteor shower occurs on the nights of April 20-22 this year, with its maximum at 23h Universal time on the 21st. Since the moon is at last quarter on the 18th, it will not interfere with observations. A total of 15 meteors per hour may be seen by a single observer at the peak of this event. W. H. G.

MINOR PLANET PREDICTIONS

Victoria, 12, 10.3. April 6, 14:43.4 −21-42; 16, 14:36.8 −20-44; 26, 14:28.2 −19-24. May 6, 14:18.7 −17-49; 16, 14:10.0 −16-09; 26, 14:03.2 −14-35. Opposition on April 29.

Hebe, 6, 9.7. April 26, 15:48.1 +2-51. May 6, 15:39.9 +3-48; 16, 15:30.8 +4-28; 26, 15:21.6 +4-48. June 5, 15:13.3 +4-44; 15, 15:06.6 +4-19. Opposition on May 16.

Vesta, 4, will be of the 7th magnitude during April, readily visible in binoculars. An ephemeris of this object appeared on page 254 of the February issue.

For most of April, Vesta will be in northeastern Sagittarius, where the rich background of stars may aid observations of the asteroid's motion from night to night. The opposition date is July 2nd.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

GRAPHIC TIME TABLE OF THE HEAVENS — 1960

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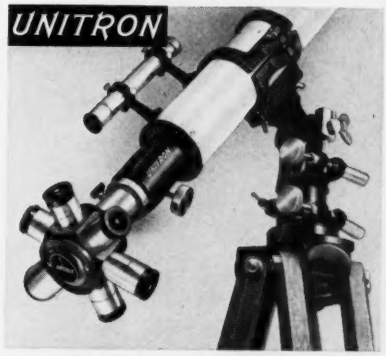

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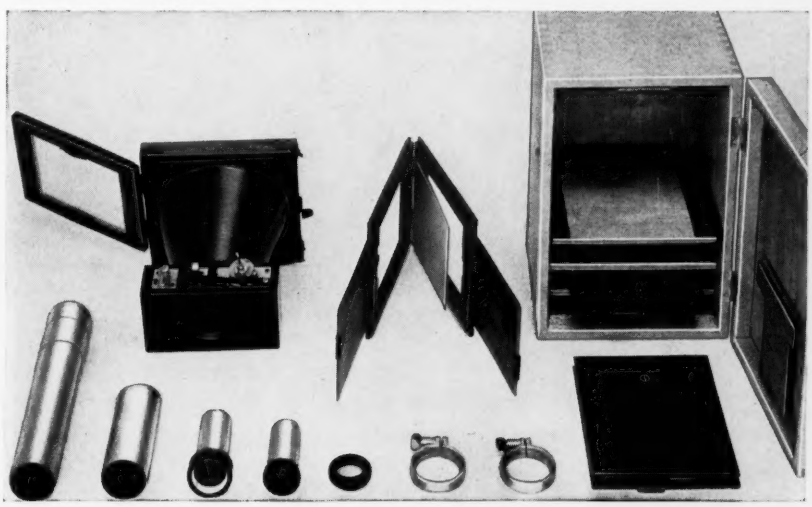

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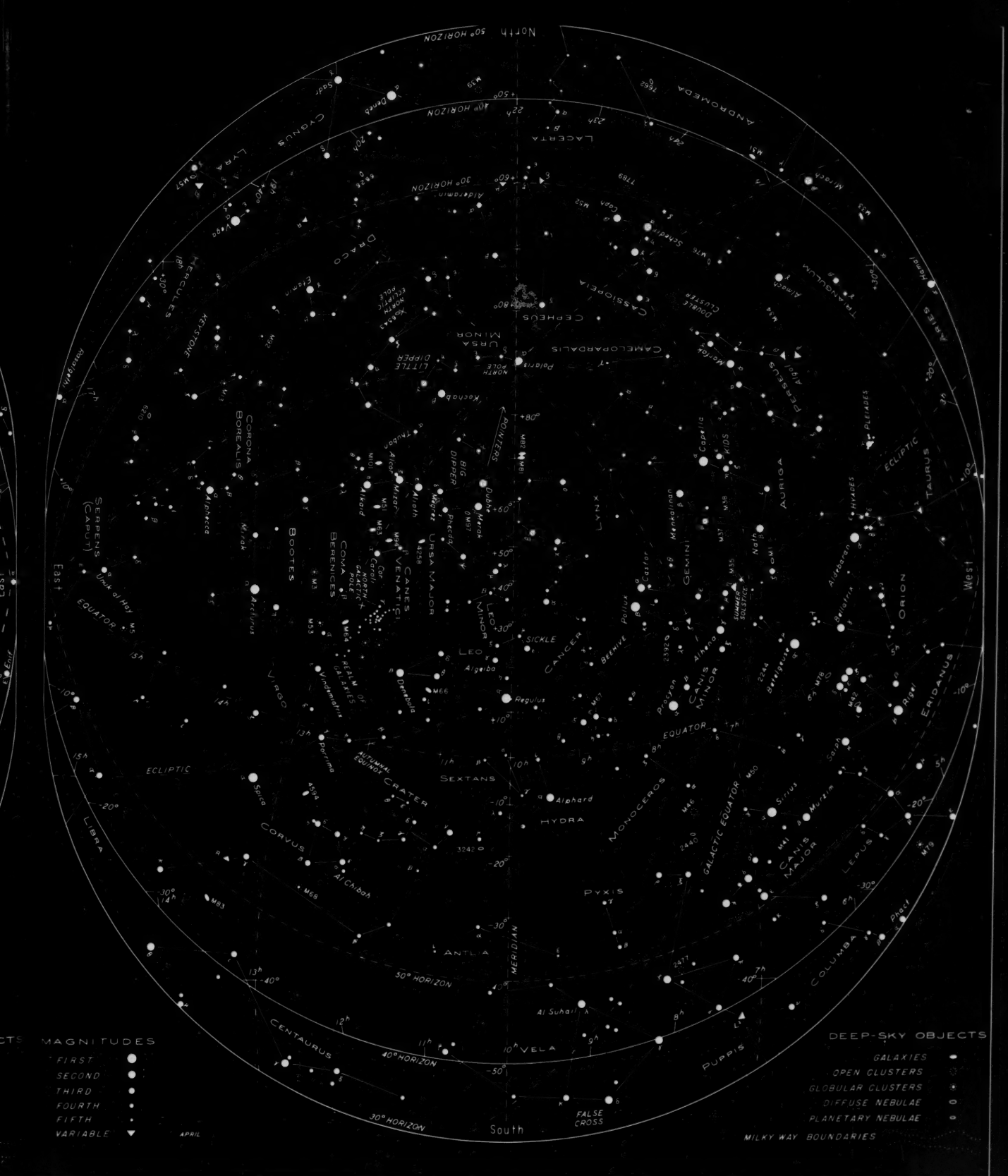
SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south at 11 p.m. and 10 p.m., local time, on the 7th and 22nd of June, respectively; also, at 9 p.m. and 8 p.m. on July 7th and 22nd. For other dates, add or subtract ½ hour per week.

At this season the southern Milky Way stretches across the sky from northeast to southwest, and appears as a misty band of light with many bright stars adorning it. Toward the north, Serpens and Corona Borealis are well placed, while Hercules nears the meridian.



STARS FOR APRIL

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 22nd of April, respectively; also, at 7 p.m. on May 7th. For other dates, add or subtract ½ hour per week.

At chart time, Orion is near the western horizon, an indication of spring. Two popular constellations that are now on the meridian are Leo the Lion and Hydra the Water Monster. Bright Regulus is almost due south, while Alphard and the Hydra's head are nearby.

QUESTAR NEWS • *April-May, 1960*

This little fellow is a flying squirrel, a nocturnal native of Sarasota, Florida. Mr. and Mrs. Ralph Davis encourage his visits to their bird feeder by putting out a slice of bread each night. This model fee works so well they now have three regular customers.

In order to show how very tiny the flying squirrel really is, Mr. Davis set up this steel ruler behind the piece of bark which conceals the feeder dish. We find our eyes are so stubborn that they present a problem. The Davis prints are size 8 x 10, which makes this tiny squirrel more than twice life size on them. But no amount of effort can persuade our eyes to regard him as only 2 inches high. The enlarged flying squirrel is plain ordinary squirrel size, our eyes say, and they refuse to let us imagine the true size of the little beasts. When we reduce the picture to actual size, we have no trouble. This forcefully illustrates to us once more the great complexity of human vision.

This grainless photograph, which shows each hair and great detail of bark, was made with the Davis' Questar on ADOX KB-14 35-mm. film with strobe light. The camera is deep in the house, 30 feet from the outdoor feeder, which is outside a plate-glass window. The two electronic flash units are inside the window, out of the weather. This setup has long been used for photographing birds in color. The advantages are that once lights are correctly placed and cameras focused, every exposure is a perfect one. Birds do not react at all to the very brief and brilliant flash.

Questar owners are aware that most windows, even those of plate glass, seriously degrade the image. Ordinary window glass is particularly bad. We have ascribed the high resolution in pictures like the above to the fact that the plate glass was very near the object and quite far from the telescope.

A few weeks ago, we received a phone call from Mr. Gerould of the Chase Manhattan Bank, second largest in the country. He told us that they were building the world's sixth tallest building, whose 60th floor now dominates the Wall Street district where it stands. It is also the highest building built for 25 years.

An officers' restaurant will be located on the north side of the 60th floor, overlooking all of Manhattan from river to river, a truly breathtaking sight. It had been decided, said Mr. Gerould, to mount two Questars so the bankers could examine this grand scene through the plate-glass windows. Would we bring up a Questar and test the quality of plate glass, to determine whether special quality plate was necessary? Indeed we would, for we were most curious ourselves.

Arriving there we were taken to the 48th floor on a fairly clear day, and to our great satisfaction found the standard Libby-Owens-Ford plate glass entirely satisfactory. With Mr. Gerould we found that the glass interfered but little save at 160x, and even at this high power was no great drawback to observing. Views at Questar's 40x and 80x (actually 48x and 96x) were quite acceptable, both near and far from glass at various angles to it.

As we understand it, modern plate glass is made on a continuous basis, being simultaneously ground top and bottom while in motion. We can attest its clarity, parallelism, and freedom from strain. The interesting things that might be done by way of indoor observing, provided specially selected extra-high quality sheet were available, leap at once to mind. O man — to stay indoors, snug and warm, while perfectly free to observe the heavens — that is living! We know, for we once had a polar telescope, a 6-inch refractor over a 12-inch flat. Since the cold open end was down, tube currents were practically nil. Warm air stayed near the eyepiece, without moving, since the ocular was upstairs and indoors where it was warm. The trouble with conventional refractors, of course, is that the highest point is the coldest, due to radiation, which promotes a constant internal convection current of air, to the detriment of seeing, as W. H. Pickering pointed out many years ago.

Mr. Arthur Page, president of the Astronomical Society of Queensland, has most graciously sent us the following anecdote: Prof. Bart J. Bok, the director of Mount Stromlo Observatory, and Mrs. Bok were guests of honor of the Queensland Society on June 17, 1959. As the 4 members of the reception committee awaited the guests' incoming plane at the airport, they suddenly realized that none had ever seen their distinguished guests. Then someone remembered that Dr. Bok had promised to bring his Questar, so they decided to *"look for the Questar case — he must be carrying it by hand! Sure enough, identification and recognition were simultaneous. Clutched firmly in Prof. Bok's right hand was the case containing the Questar. A few minutes later when informed of this, Prof. Bok turned to Mrs. Bok and said 'Priscilla, we go home! They seem more interested in the Questar than in us!" No little wonder that our guests of honour endeared themselves to us with their charm and sense of humour.*

. . . "The highlight of the Society's Centenary celebration was Dr. Bok's address to the Institute of Physics and the Society at the University of Queensland, on 'The Structure of Our Galaxy.' . . . At this meeting also, members of the Society obtained their first look at Prof. Bok's Questar, which he left in the Society's care during his visit."

In early 1959, when the splendid current model of the Linhof heavy-duty tripod was introduced, it was in very, very short supply. We had so much difficulty getting shipments from Munich that we finally put in a whacking big order for several dozen to be shipped here to our factory, as sort of a reserve supply over the number held for us in New York by the importer. As of January, 1960, the price of the tripod jumped from $139.50 to $179.50, and the pan head rose by $10 to $69.50. By the time this page is printed we may still have a few left at the old prices. Our policy is not to raise the price of any item until we have to purchase more at the higher price. So while our supply of tripods lasts, we will pass the savings on to you.

Speaking of rising prices, the cost of each Questar part keeps on upon its steady rise. The average increase is perhaps 8% or so per year. A few sharper rises last year brought us face to face with the probability of having, after 5 years, to raise Questar's price.

We are pleased to announce, however, that we can maintain the present price for quite some time. What has saved the day is that in 1959 our volume of business doubled, with consequent savings on overhead costs. As we write, public acceptance continues to grow. Questar was announced 6 years ago in these pages alone. Today our advertising addresses itself to more than 16 times this journal's readership.

Keeping everlastingly at it continues to teach us better ways of making Questars. Last year, besides several minor improvements, we perfected a new type of all-metal barrel assembly, precision machined in the engine lathe as a whole unit to insure perfect alignment. In production now are 4 more radical improvements that each instrument will soon carry. Almost always such improvements cost more but in 2 cases the increased cost was more than offset by savings in assembly time, a happy situation. Questar still costs only $995 in a beautiful British fitted leather case, delivered postpaid, fully insured. Terms available. May we send our 32-page booklet?

Laurence Braymer
President

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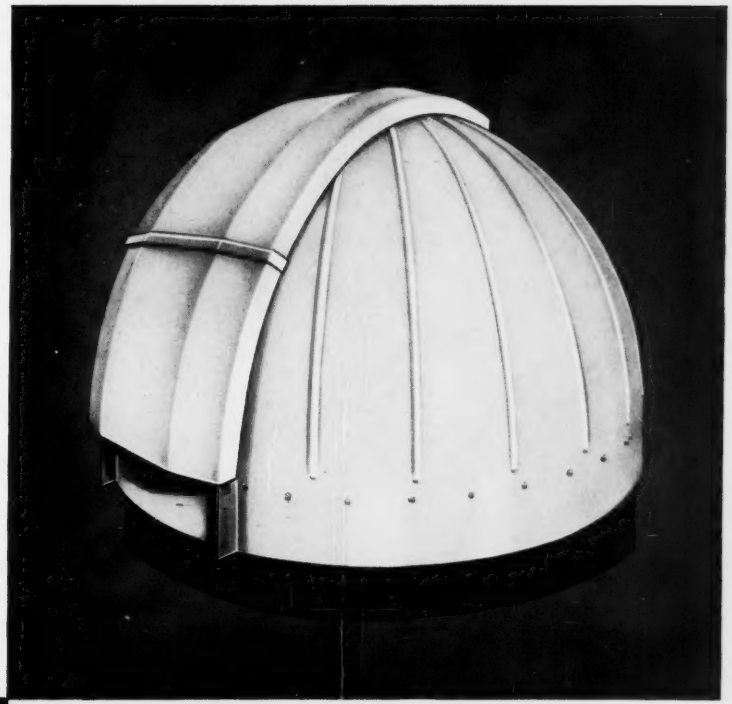

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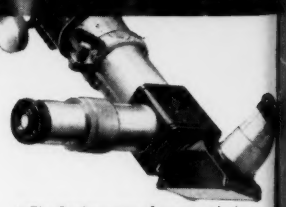

‡† The Duetron, one of many exclusive Unitron accessories for multiplying viewing thrills, permits two people to view at the same time. It is shown mounted on a Unitron 4" Equatorial Telescope, Model 155.

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